FINAL DRAFT

GUIDELINES FOR DESIGNS FOR

ENERGY EFFICIENT / PASSIVE SOLAR HOUSING

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for:

CANADA MORTGAGE AND HOUSING CORPORATION

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I. INTRODUCTION

The purpose of the Guidelines is twofold:

- To provide a uniform set of design criteria for the architects participating in the Designs for Energy Efficient / Passive Solar Housing project. The design citeria are to ensure that the house types, sizes, site constraints, technical and comfort parameters suit the mass market of tract housing at the subdivision scale.

- To provide rapid and visual graphical methods for thermal design during the conceptual or initial stage. The tools presented allow the graphical calculations necessary for the

  control of space temperature fluctuation

  and

  assessment of heating energy requirement.

The Guidelines are therefore divided into two distinct parts (A and B). Further details, refinements and design graphs are included in the Appendices to the Guidelines.

PART A - D E S I G N C R I T E R I A

The purpose of this part is to ensure that the Energy Efficient / Passive Solar Designs provided by the designers participating in this project meet the general requirements of the mass market of new subdivision housing and to allow for a certain uniform standard of comfort.

The following subjects are covered in Part A:

- Lots and Orientation
- Unit Types
- Insulation Levels
- Technical Design Parameters
- Comfort

1. LOTS AND ORIENTATION

- Assume lots to be either on the north or south side of true cardinal east-west streets.

- Assume flat sites. Minor grade manipulation permitted within context of simple subdivision grading standards.

- Setback requirements:

  i) Front yard 6m (all unit types).

  ii) Rear yard 7.5m minimum, however for unit designs for lots on the north side of a street provide adequate rear yard setback to assure that the solar access for windows in a unit on a lot immediately north is not impinged by the shadow on January 21, 9 AM and 3 PM.

  iii) Side yards

    a) single family - combined side yards of 1.83m with no less than 1.22m between houses.

    b) semi detached - side yard not less than 1.22m.

    c) townhouse - no side yard, assume internal unit.

2. UNIT TYPES

  i) General for all units:

    a) Space standards no less than Residential Standards NRCC No. 15563.

    b) Designs suitable for mass market. Assume an experienced developer builder as a hypothetical client.

    c) Design south facing roof slopes to suit future addition of active solar sytems (hot water heating, photovoltaic).

  ii) Single Family Units:

    a) 130 to 150 m^2 gross floor area exclusive of garage and required storage

    b) 18m x 30m and 15m x 30m lots

    c) 3 bedroom, 1-1/2 baths

    d) 2 storey or 2 storey with walkout basement

    e) single car garage at grade

iii) Semi Detached Units:

a) 120 to 140 m^2 gross floor area exclusive of garage and required storage

b) 22m x 30m and 25m x 30m lot per pair of units

c) 3 bedroom, 1-1/2 baths

d) 2 storey or walkout basement

e) single car garage at grade

iv) Street Townhouse Units:

a) 110 to 130 m^2 gross floor area exclusive of garage and required storage

b) 6m x 30m and 5m x 30m lots internal

c) access from street to garden without passing through habitable space

d) 3 bedroom, 1-1/2 baths

e) 2 or 3 storey

f) single car garage at grade

v) Block Townhousing:

a) 120 to 130 m^2 gross floor area exclusive of garage and required storage

b) 34 units per hectare

c) 3 bedroom, 1-1/2 baths

d) 2 storey

e) assume surface parking

3. INSULATION LEVELS

Provide thermal insulation in walls, ceiling, etc. to meet the following thermal resistance levels:

MINIMUM THERMAL RESISTANCE (R VALUE), $m^2.C/W$

Building Assembly	Location and Celsius Degree Days		
	OTTAWA 4597	REGINA 5877	VANCOUVER 3024
Wall assemblies above ground level (other than foundation walls) separating heated spaces from unheated space or the outside air	3.4	3.9	2.8
Foundation wall assemblies separating heated space from unheated spaces, outside air or adjacent earth	2.2	2.2	2.2
Roof or ceiling assemblies separating heated space from unheated space or the exterior	5.3	6.0	4.4
Floor assemblies separating heated space from unheated space or the exterior	4.7	4.7	4.7
Perimeters of slab-on-ground floors that are less than 600mm below adjacent ground level (insulation only)			
(a) slabs where heating ducts, pipes or resistance wiring are embedded in or beneath the slabs	1.6	1.9	1.2
(b) slabs other than those described in (a)	1.1	1.4	0.7

The above table is extracted from "Proposed Changes for the Next Edition of the Measures for Energy Conservation in New Buildings", a National Research Council of Canada publication. Refer to this publication for further details.

4. TECHNICAL DESIGN PARAMETERS

- Employ structural materials and designs common to subdivision housing.

- Employ energy conscious details, windows and doors. For guidance and standards see C.M.H.C. Documents NHC 5417 81/06 "Energy Conservation in New Small Residential Buildings" and NHA 5488 82/11 "Energy Efficient Housing Construction". Further Details available in H.U.D.A.C. "Builder's Guide to Energy Efficiency in New Housing".

- Identify elements in the design that would be beyond the norm for tract housing. Be mindful of the benefits of such elements versus the costs involved.

5. COMFORT

i) Air Quality

The house must have a minimum of 0.5 air changes per hour ventilation ability that is controlled by mechanical means to ensure adequate air quality.

For purpose of calculation:

a) Ventilation is assumed to be continuous

b) Heat recovery systems, if utilized, are considered to only modify the controlled ventilation rate.

ii) Temperature Swings

The house must be constructed such that temperture swings within the building's livable area are limited to 7 Celsius degrees above normal indoor temperature during the heating season. For design purposes the indoor temperature shall be 20 degrees Celsius.

PART B - THERMAL PERFORMANCE

The purpose of this part is to discuss briefly the principles of Energy Efficient / Passive Solar design and to provide rapid graphical methods for the quantitative assessment of thermal performance of the conceptual design.

The following subjects are covered in Part B:

PURPOSE AND OUTLINE

BASIC PRICIPLES OF PASSIVE SOLAR DESIGN

- The Interacting Elements of Passive Solar Design
- Envelope Upgrading and its Limits
- Solar Energy Collection and its Limits
- Thermal Mass Benefits and its Limits
- General Rules of Thumb of EE/PS Design

CALCULATION OF TEMPERATURE SWING

- General Principles
- Graphical Calculation of Temperature Swing
- Sample Calculations

CALCULATION OF HEATING ENERGY REQUIREMENT

- Outline
- Graphical Calculation of the Above Grade Heat Loss Coefficient
- Graphical Calculation of the Below Grade Losses
- Graphical Calculation of the Auxiliary Heat Requirement
- Shading Effects
- Overhang Shading
- Protruding Wall Shading
- Mass Effects
- Sample Calculations

1. PURPOSE AND OUTLINE

During preliminary or conceptual design of Energy Efficient Passive Solar housing one requires a tool that allows a quick assessment of the adequacy of the balance between the major thermal components. Specific client requirements, site and climate constraints as well as the basic design concepts need to be synthesized, tested and weighed before proceeding with the detailed design. Such tool should preferably be visual, indicating the interaction of the thermal processes at work and indicating, again visually, the relative magnitude of the effects of potential improvements and alternate strategies. Such preliminary assessment of the conceptual design is the purpose of the material that follows.

The more accurate measurement of the expected performance with the help of detailed manual calculation methods or computerized methods is outside the scope of the present discussion, although it may be necessary at a later stage of the design development. Appendix C includes a condensed overview of such methods.

It is assumed that the user is familiar with the basic concepts of energy efficient passive solar design. Nevertheless, a short discussion of certain aspects of such design and suggestions aimed at facilitating the selection of a design strategy precede the presentation of the graphical calculation methodology.

Thermal performance calculations for energy efficient passive solar residential structures are divided into two areas:

- Calculation of the Space Temperature Swing during sunny winter days.
- Calculation of the Seasonal Purchased Heating Energy Requirement.

Control of the room temperature fluctuation during sunny winter days is a more fundamental design requirement than the energy performance and therefore is discussed first. The conceptual design, the sizing of the glass area and of the thermal mass, and the configuration of the spaces is best carried out with the help of the temperature swing calculation tool.

The design tools are arranged in such a way that initially an approximate graphical calculation requiring minimum effort, is carried out. The results can be refined after one of the trial designs is selected. Shading effects and mass effects can be added to enhance further the accuracy of the initial graphical results. With unusual designs and where still greater accuracy is desired, manual calculations can be carried out with the help of calculation forms that are provided.

2. BASIC PRINCIPLES OF PASSIVE SOLAR DESIGN

2.1 The Interacting Elements of Passive Solar Design

The major thermal elements in Energy Efficient Passive Solar design are:

- Insulation
- Airtightness
- Solar Gains
- Internal Gains
- Thermal Mass

The thermal performance is determined by the proportions and the interaction of these thermal elements:

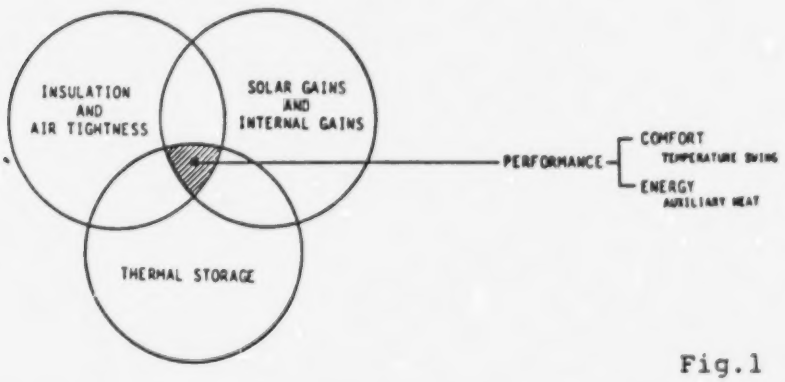


Fig.1

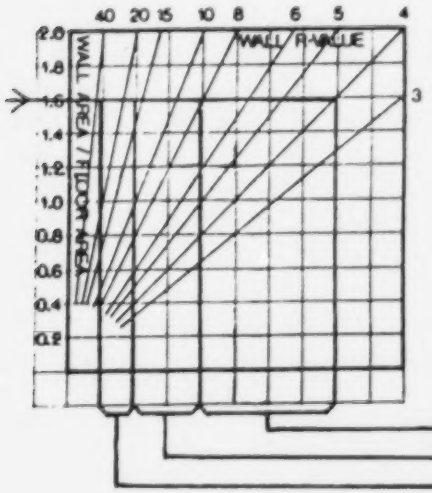
Thermal design is in essence the harmonious balancing of the thermal elements within the design objectives and the constraints of occupancy, local climate and economic considerations.

None of the thermal elements can be treated in isolation as changes in any one affect the performance of the others. As an example of such interdependence consider the assessment of the effectiveness of additional insulation. The common sense reaction is to expect that the seasonal benefit will be proportional to the reduction in the rate of heat loss from the house. This idea is incorrect however because of the interplay between the thermal elements. The added insulation will reduce the need for heat in the warmer spring and fall months so that there will be more days when the house will not need any heating, i.e. days when all the heating needs are provided for by the heat from appliances, bodies of occupants and solar gains. The shortened heating season will utilize less of such useful internal energy. Utilization of the solar energy will be reduced because of the more frequent overtaxing of the storage mass as well as the shortened heating season. Solar energy contribution could be enhanced by added thermal storage. The overall energy savings however will not be as great as expected.

2.2 Envelope Upgrading and its Limits

Envelope upgrading includes all measures that reduce the heat loss from the structure. Insulation, air tightness and low loss glazing fall in this category.

Continued envelope upgrading follows the law of diminishing returns. The effectiveness of repeated doubling of wall and roof insulation is best illustrated on the Above Grade Heat Loss graph. In the example below the cost of the second doubling of insulation will be at least twice as high as in the first step, but the potential for saving energy will be only half as much. Therefore, the cost effectiveness of the second step will be lowered in the ratio of four to one - spend twice as much and save half as much.



WALL LOSS

Energy Saved:
First Doubling (R4 added)
Second Doubling (R8 added)
Third Doubling (R16 added)

Fig.2

The law of diminishing returns holds in the static consideration of the changes to the heat loss coefficient of the house. If the total dynamics of internal gains, solar gains and mass effects are brought into the picture, then the law of disappearing returns obtains. Consider that it may be possible to improve the envelope to the point where the internal gains and solar gains provide all the necessary heating energy, i.e. no auxiliary heat is required. It is obvious that any further improvement to the envelope would be useless since it would not produce any energy savings. The effects of the fast disappearing returns become pronuonced considerably before the point of self-sufficiency is reached. This may be noted in the calculated examples given later.

2.3 Solar Energy Collection and its Limits

The ideal window should have high resistance to heat flow and at the same time allow the solar energy to pass through with minimal interference. Ordinary glass meets such requirements only partially. Windows with improved performance are being developed. Higher resistance to heat flow results from multiple glazings, infrared suppressing films, convection suppressing devices, use of low conductance gases or vacuum between glazings and use of insulating shutters or blinds at night.

With ordinary glass in Canadian climate only triple glazing in the south exposure provides a definite net contribution to the heating of a house. Energy is saved if the area of triple south glazing is increased. Glass in the north, west and east exposures, as well as horizontal skylight glass, is a net loser of energy. This holds true for triple and quadruple glazing also. South windows with double glazing are neutral (possibly slight gains or losses) regarding heating energy consumption. Paradoxically though replacement of double glazing with triple glazing will save more energy in the north, east and west exposures than in the south exposure. This is because triple glazing reduces heat losses by the same amount in all exposures, but cuts out more of the solar energy in the south exposure than in the exposures that have lower solar gains. This consideration applies only to the situation where the distribution of glazing is fixed in each exposure and the effectiveness of triple glazing vs. double glazing is being considered.

The most cost effective energy conservation measure is locating most of the required window area in the south wall of the house and as little as possible in the other walls. Since every house requires a certain amount of glazing, this rule holds with double and even single glazing. If you must have glass, even poor glass, then locate it in the south wall. Increasing the south glass area beyond the minimum required by the Residential Standards or architectural design requirements should only be considered if triple glazing, quadruple glazing or high performance double glazing is used.

Solar transmittance of glazing can be increased through the use of low iron glass, plastic film for the third (protected) pane and antireflection films and finishes.

Moderately inclined glass (20 - 30 degrees from vertical in Canada) collects winter solar energy better. Disadvantages are increased construction cost, difficulties with sealing against the weather and increased overheating problems in summer.

Continued increasing of the solar aperture also follows the law of diminishing returns. Small solar gains can be utilized practically 100% by the house. As the solar gains increase, however, a mismatch between the supply and demand for solar heating energy occurs more frequently. There are more and more hours when the solar gains exceed

the heating requirements of the house. The efficiency of utilization of solar energy is lowered. Also, the point is approached where the temperature swings during sunny winter days exceed the comfort range. Added thermal mass can correct both of these problems but there is a limit for that also as discussed later.

Generally the maximum south window area is limited by the maximum allowable space temperature swing. The amount of thermally heavy interior surfaces is the major factor in determining the optimum area.

The designer should appreciate that venting of excess heat in winter and drawing of curtains or shutters during such sunny winter days is totally counterproductive. The excess glass that causes such problems loses heat continuously, both during the sunny and the cloudy days, as well as during the night, but at the same time such glass is prevented from gaining substantial amounts of useful solar energy by curtains or venting. This underlines again the importance of the proper balance between glass and mass.

2.4 Thermal Mass Benefits and its Limits

Thermal mass increases the efficiency of the collection of solar energy and allows larger solar collection apertures by preventing excessive temperature peaks during sunny days. Cost effective ways of of providing thermal mass are the use of interior masonry partitions of brick or concrete block and use of extra thick or double layer drywall. Massive exterior walls with the insulation placed on the outside may be less cost effective. Massive floors are thermally more efficient than walls or ceilings. They should preferably not be covered with carpets. The calculated examples given later indicate the magnitude of this effect. The mass of the basement can be utilized if special air circulation fans and ductwork are installed for this purpose. The basement walls and floor must be well insulated on the outside in this case.

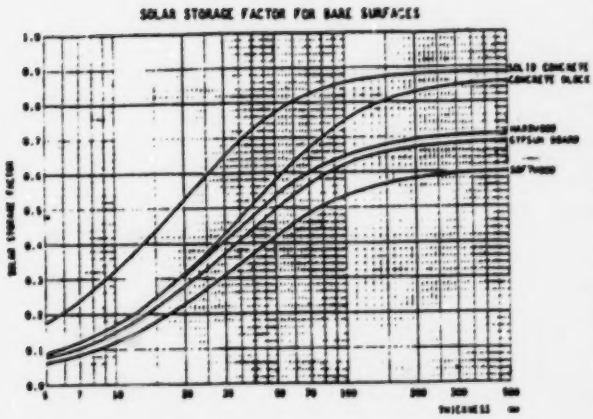


Fig.3

Thick massive elements are not effective beyond a thickness of 30 to 50mm. Graph at left is not used with the present method, but it illustrates this point well. Painting of the massive components in darker colours has little effect due to the fact that solar radiation is trapped inside the room and very little of it can escape even with light coloured finishes. This effect can be observed by looking at a window from the outside on a sunny day and noting the almost black appearance of a window without curtains, regardless of the colour of the interior finishes. Anything that makes the window appear lighter, e.g. curtains, objects near windows, light coloured window frames (with solar absorptivity less than .9), will reduce the collection of solar energy correspondingly.

A rock filled bin with ducts and a special fan can be used as additional mass. Effectiveness of storage in such a bin is directly proportional to the temperature difference and therefore generally involves the creation of hot pockets with temperature swings that are much higher than those acceptable in the living space. It may be noted in this connection that thermal mass located directly in the space receiving the solar radiation works more efficiently as it can store substantial quantities of heat without any temperature swing.

Basic mechanisms of energy storage in thermal mass are discussed in further detail in the description of the graphical temperature swing calculation method. The effectiveness of added mass and its limitations are best determined with the help of the graphical method. The designer should experiment with this graph in order to appreciate the usefulness of the various strategies that can be followed.

2.5 General Rules of Thumb for Energy Efficient / Passive Solar Design

- Keep plan form simple, avoid excessive projections and indentations, especially on south facing wall in order to reduce the building envelope area and to avoid shading of south windows.

- Group major habitable rooms on the south side of unit.

- Locate majority of windows on the south side, minimize windows on the other elevations, particularly north.

- To assist in solar storage consider the use of interior masonry and concrete slabs. Preferably keep such surfaces bare.

- Locate fireplace and flues off exterior walls.

- Consider openness in planning to allow for easy flow of warm air to all parts of unit and for cross ventilation during warm seasons.

- In the design of semi detached and townhouse units take full advantage of shared walls to reduce heat loss.

- Generally more insulation should be provided at the ceiling than in the walls because it costs less to install insulation at the ceiling. Adding of more insulation in the walls involves higher installation costs due to the required changes in the structure or the use of higher cost type of insulation.

- Little extra cost is involved in upgrading the basement wall insulation, particularly if it is applied to the exterior of the wall.

- Insulation under the basement floor is least effective as the ground itself already provides resistance to heat flow equal to some 100 mm of insulation. Basement insulation increases the depth of penetration of the frost line. With large amounts of insulation it is possible to lower the frost line so much that the footings may be endangered.

- Careful detailing of the vapour barrier, caulking of cracks and consideration of heat losses when detailing connections at floors, walls, ceilings and at corners are the most cost effective items as they can be provided at very little cost or no cost.

- The maximum allowable south glass area depends on many variables, but the following approximate rules can be used. The clear glass area in typical windows is about 75% of the gross area (masonry opening area). Total room surface area equals approximately four times the floor area. With these assumptions the gross window area in any south facing room of standard light construction should not exceed 12% of the floor area in order to limit the maximum room temperature swing to 7 degrees C during sunny winter days.

- If 25% of enclosing surfaces of the room (walls, ceiling and floor) are of heavy construction (brick, block or concrete), then the window area can be increased to 14.5% of the floor area.

- Similarly with 50% of the enclosing surfaces of heavy construction the window area can be 18% and with all heavy construction it can be 36% of the floor area.

- The rule of thumb formula is:

$$12\% \times 3 / (3 - 2 \times F\% / 100)$$

where F is the percentage of heavy construction. It is assumed that the floor is carpeted, whether of wood or concrete.

3. CALCULATION OF TEMPERATURE SWING

3.1 General Principles

Solar energy comes into a passive solar heated structure very unevenly. The incoming energy during sunny winter days exceeds the immediate heat losses and such excess is stored in the mass of the structure.

Solar energy is stored in two distinct ways simultaneously. A portion of it is absorbed directly in the materials surrounding the spaces with south glazing. This occurs while the solar energy is still in the form of radiation, without involving the air in the space and therefore, without causing a rise in the space temperature. Such radiative solar storage can take place only in surfaces that can "see" the solar gains, i.e. are located in the space receiving the radiation. The radiation is largely distributed over all such surfaces by repeated reflections and infrared re-radiation. The floor, however, plays a special role in this process since the solar "window image" is on the floor most of the time during such clear winter days.

The remainder of the solar energy causes the space temperature to rise and thus, to store all of such remaining energy in materials that can sense such temperature rise. The indoor air acts as the intermediary in this process, although only a minute quantity of heat can be stored in the air itself. This process involves not only the surfaces surrounding the space receiving the solar radiation, but also adjacent spaces, basement, furniture and any remote mass storage devices that may be provided. The effectiveness of such additional storage depends on the thermal coupling between the air of the space receiving solar radiation and the thermal mass available for storage. Partitions separating the northern portion of the house, floors and ceilings to the basement impede the flow of heat into storage (and later - the flow back from storage into space). Open doors, furnace air circulation and special circulation fans contribute to such coupling.

3.2 Graphical Calculation of Temperature Swing

As discussed previously, solar gains during a sunny winter day are divided into three components: energy used to offset heat losses, direct solar storage without temperature swing and storage due to air temperature swing.

Solar Gains = Heat Losses + Solar Storage + Air Swing Storage

or

$$G = L + S + A$$

The basic strategy of the method is to determine the unknown Air Swing Storage from the Solar Gains, Heat Losses and Solar Storage.

$$A = G - L - S$$

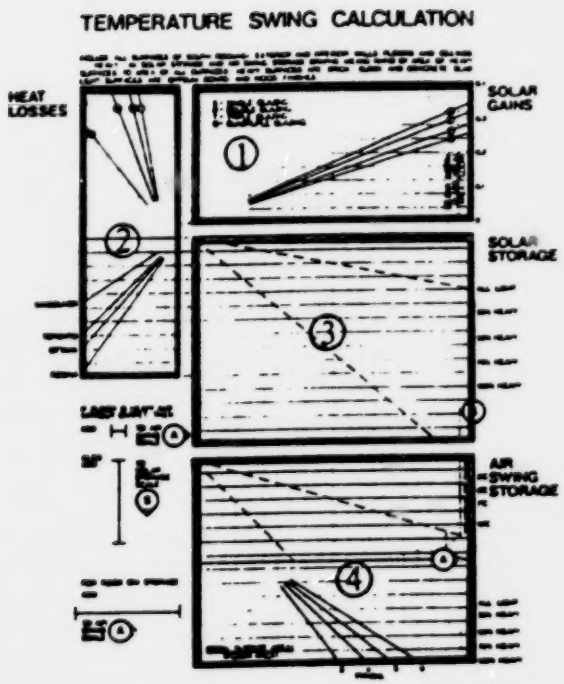


Fig. 4

The graphical calculation chart (Fig. 10 on p. 21) is divided into the same four areas:

1. Solar Gains
2. Heat Losses
3. Solar Storage
4. Air Swing Storage

The calcualation sequence is to first determine the solar gains, then subtract the heat losses and solar storage and finally to determine the temperature swing itself.

Note that in this calculation the net clear glass area must be used, as opposed to the gross window area including framing used in heat loss calculations. Clear glass area is the net light transmitting area clear of any obscuring framing. It may be 75% (60 to 90%) of the gross masonry opening area.

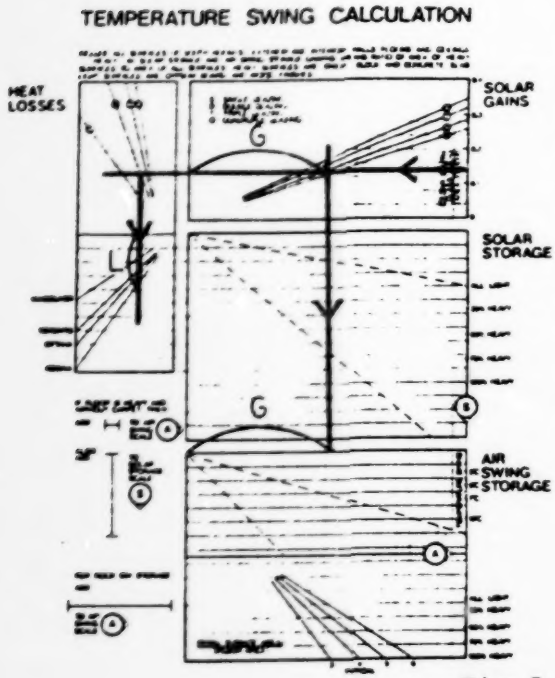


Fig.5

Enter the chart at the upper right hand side at the clear south glass area expressed as percentage of the floor area e.g. 15%. Floor area is that of the room (or rooms) with south exposure (not the total house area). Draw a horizontal line right across. Drop vertical lines from the intersections of the horizontal line with the diagonal lines of the appropriate glazing type (single, double, triple, quadruple).

Length G represents the solar gains, while length L represents the heat losses.

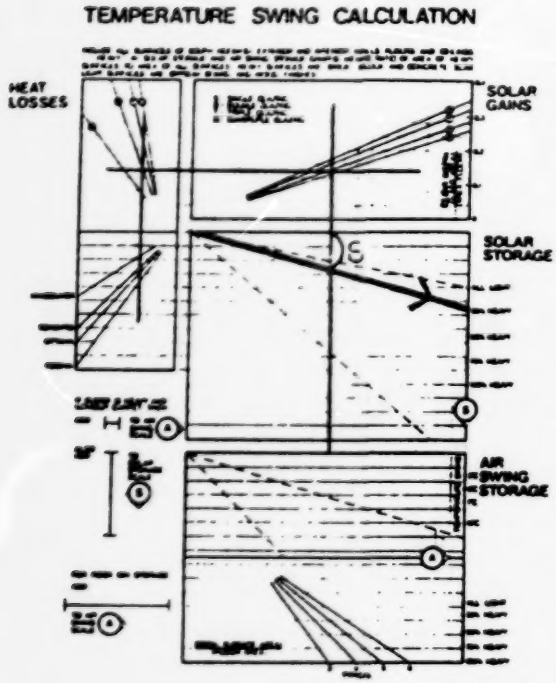


Fig.6

Solar storage depends on the type of the enclosing surfaces. Consider all surfaces that enclose the south facing room(s), but not surfaces which are in rooms that are partitioned off and face north, east or west. Surfaces are classified into light (gypsum board finish and wood finish) and heavy (brick, block, and concrete slab). Estimate the area of the heavy surfaces as a percentage of the total area of all enclosing surfaces. Either measure the areas on the plans or estimate by remembering that each room has six surfaces and that the floor and the ceiling may be twice as large as any wall. For a room of such proportions a wall represents 12.5% of the total surface area (one unit out of eight) and the floor or the ceiling represents 25% (two units out of eight).

Next draw in a diagonal line in the solar storage area of the chart, starting at the origin and through the scale at the right at the appropriate percentage of heavy surfaces. The dashed lines indicate the range of solar storage slopes. Length S represents the solar storage.

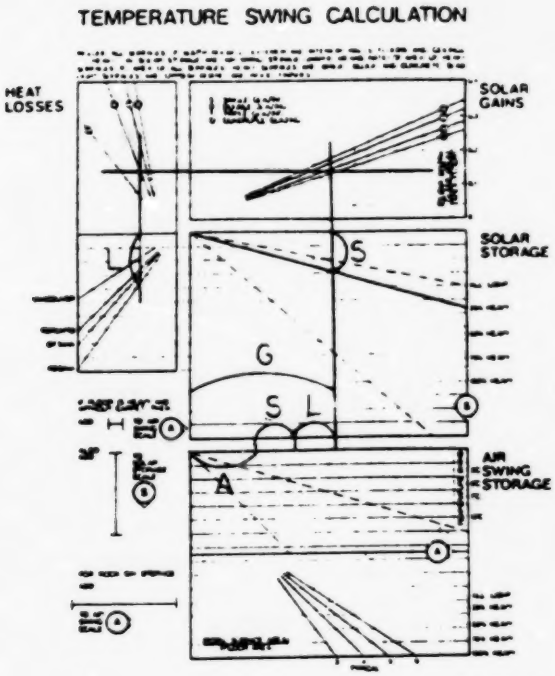


Fig.7

Now air swing storage (A) can be calculated graphically, since A = G - L - S. Lengths L and S are transferred from the Heat Loss Area and the Solar Storage Area to the top line of the Temperature Swing Area. They are laid out leftwards from the intersection of the vertical solar gains line. The remaining length A represents the required Air Swing Storage.

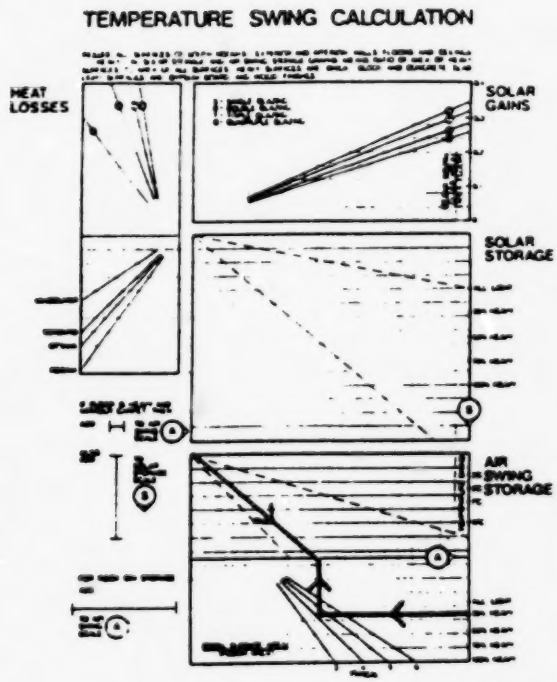


Fig.8

Next enter the lowest rectangle from the right with a horizontal line intersecting the scale from the appropriate percentage of heavy surfaces. Draw a vertical line up from the intersection with the ratio of total area of enclosing surfaces to floor area of the room (or rooms) with south exposure being considered. Note that ratio of 4 is typical. (E.g. a 4 x 6 x 2.4m room has a total surface area of $2 \times 4 \times 6 + 2.4 \times (4 + 6 + 4 + 6) = 96m^2$ and a floor area of $24m^2$. Ratio = 96/24 = 4)

The air swing storage slope is drawn next from the origin of the Air Swing Storage rectangle to the intersection of the last drawn vertical line with lower line of the same rectangle. The dashed lines indicate the range of air swing storage slopes.

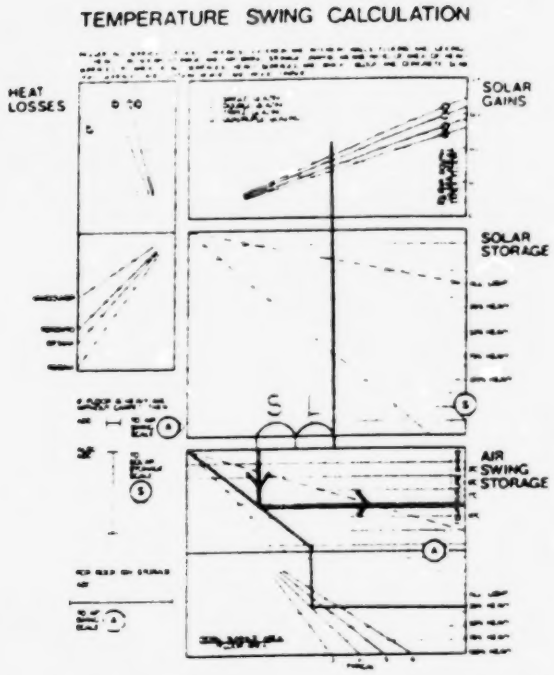


Fig.9

Drop a vertical line from the point indicating the Air Swing Storage requirement down to the air swing storage slope and then to the right to the temperature swing scale. Read the temperature swing.

The first sample calculation that follows (Fig. 11) determines the temperature swing in the Living - Dining area of the sample house described in the foldout Appendix K. The next sample calculation is for the Family Room of the sample house (Fig. 12). This room has a concrete slab floor. The calculation illustrates how the graphical method is used in the situation where a heavy floor is partially covered by carpets and furniture. In the third sample calculation (Fig. 13) it is assumed that the Family Room of the preceding calculation is of all light construction and is connected to a fan powered rock bin storage system of typical design.

TEMPERATURE SWING CALCULATION

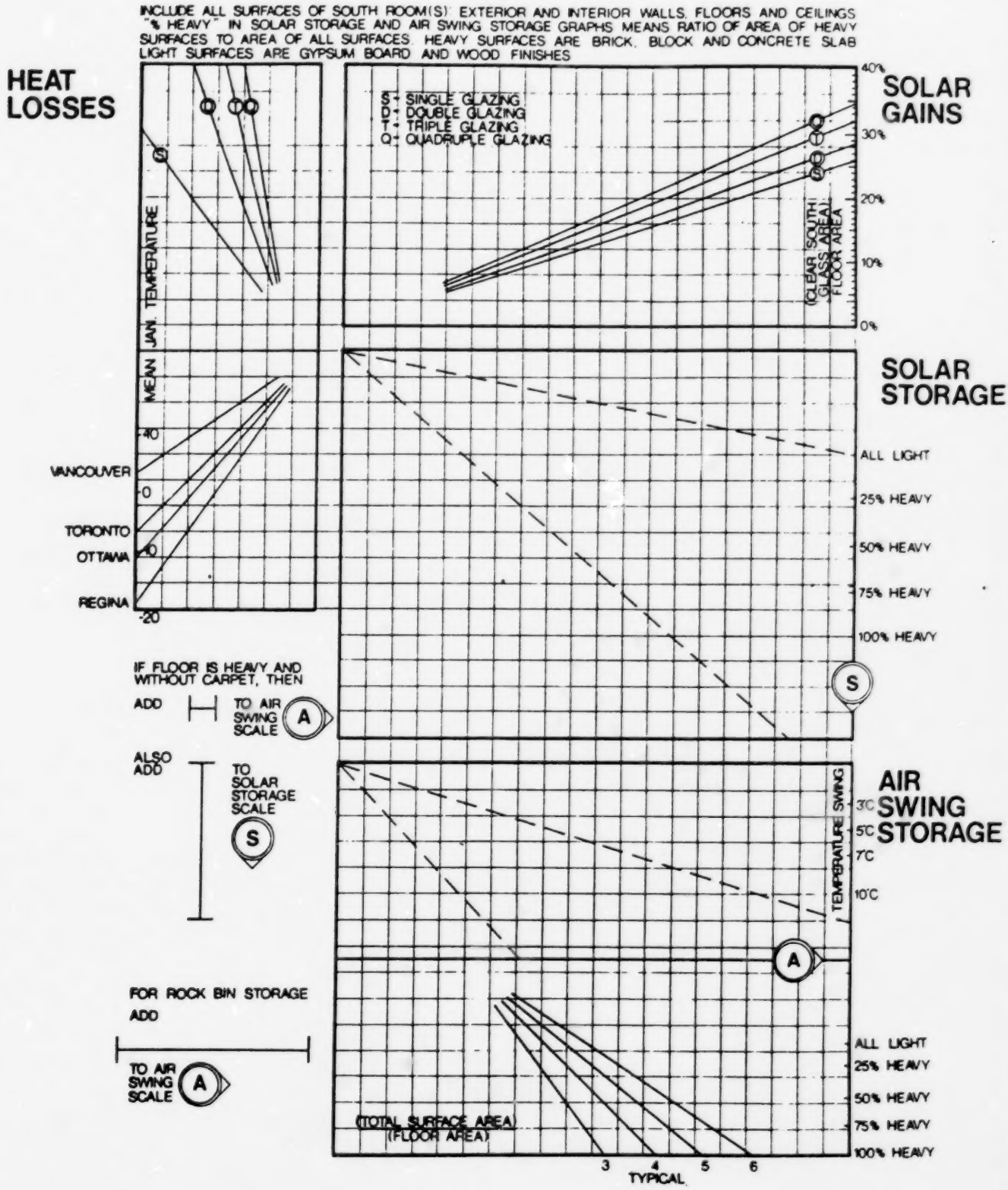


Fig.10

TEMPERATURE SWING CALCI

DINING LIVING - SAMPLE HOUSE

SAMPLE CALCULATION

For plans and section of house used in sample calculation see appendix K

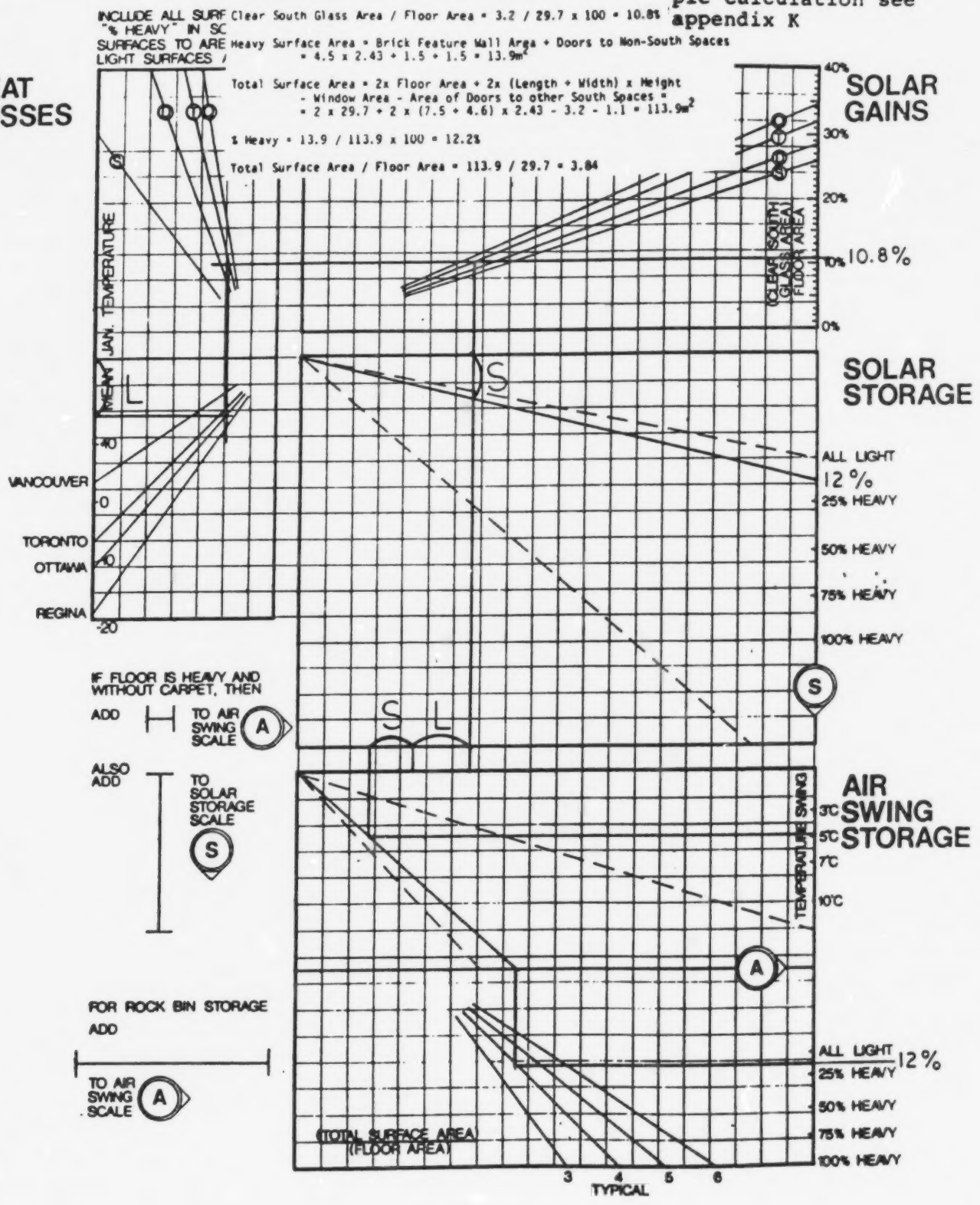


Fig.11

TEMPERATURE SWING CALC

FAMILY ROOM - SAMPLE HOUSE

Clear South Glass Area / Floor Area = 4.0 / 18.2 x 100 = 22.0%

Heavy Surface Area = Brick Wall + Concrete Floor + Door to Non-South Space
= 4.5 x 2.43 + 18.2 + 1.5 = 30.6m²

Total Surface Area = 2 x Floor Area + 2 x (Length + Width) x Height
- Window Area - Area of Doors to other South Spaces =
= 2 x 18.2 + 2 x (5.5 + 3.3) x 2.43 - 4 = 75.2m²

% Heavy = 30.6 / 75.2 x 100 = 40.7%

Total Surface Area / Floor Area = 75.2 / 18.2 = 4.13

SAMPLE CALCULATION

For plans and section of house used in sample calculation see appendix K

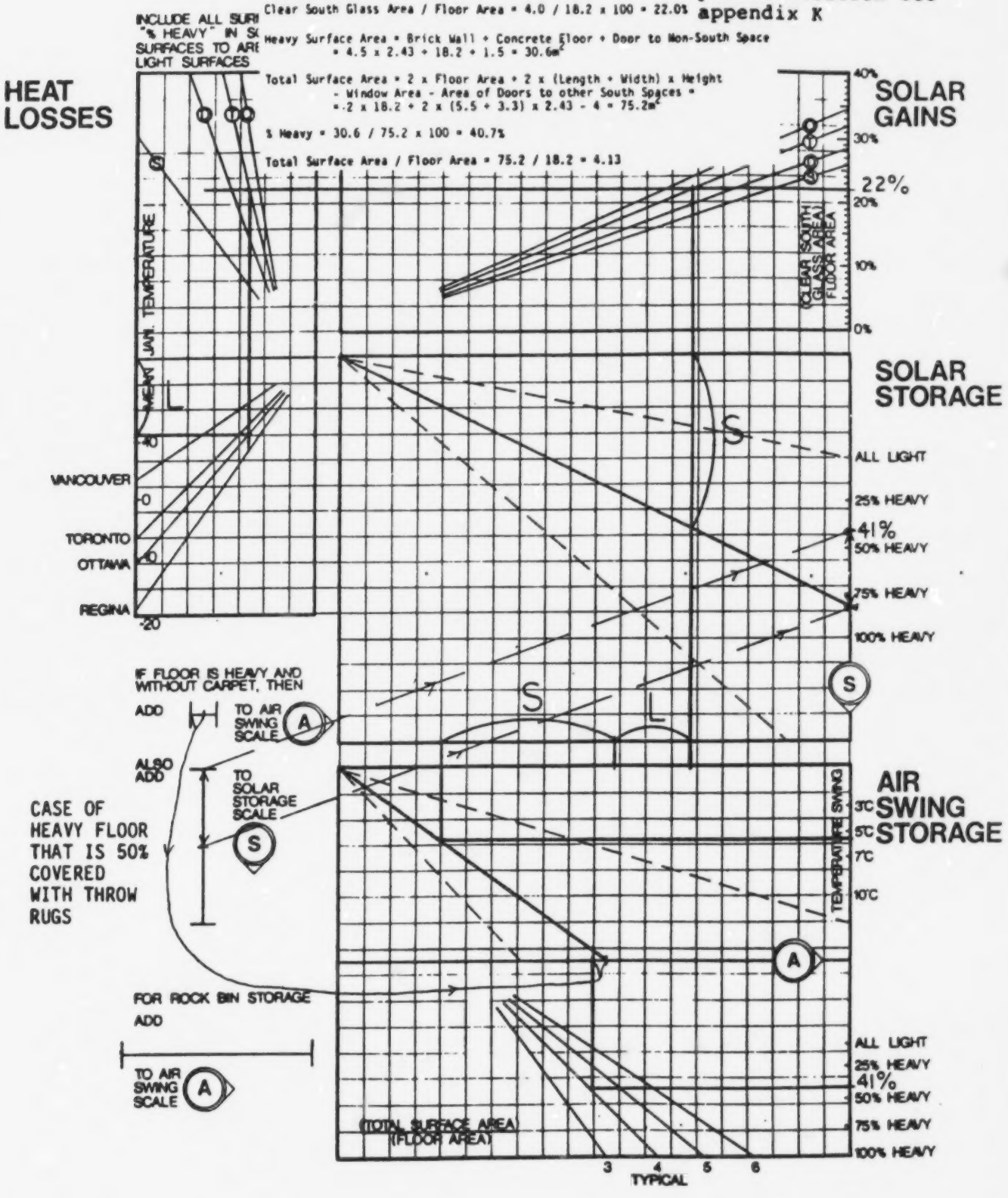


Fig.12

TEMPERATURE SWING CAI

SAMPLE CALCULATION

For plans and section of house used in sample calculation see appendix K

FAMILY ROOM

Same as preceding example, except light construction and fan forced rock storage.

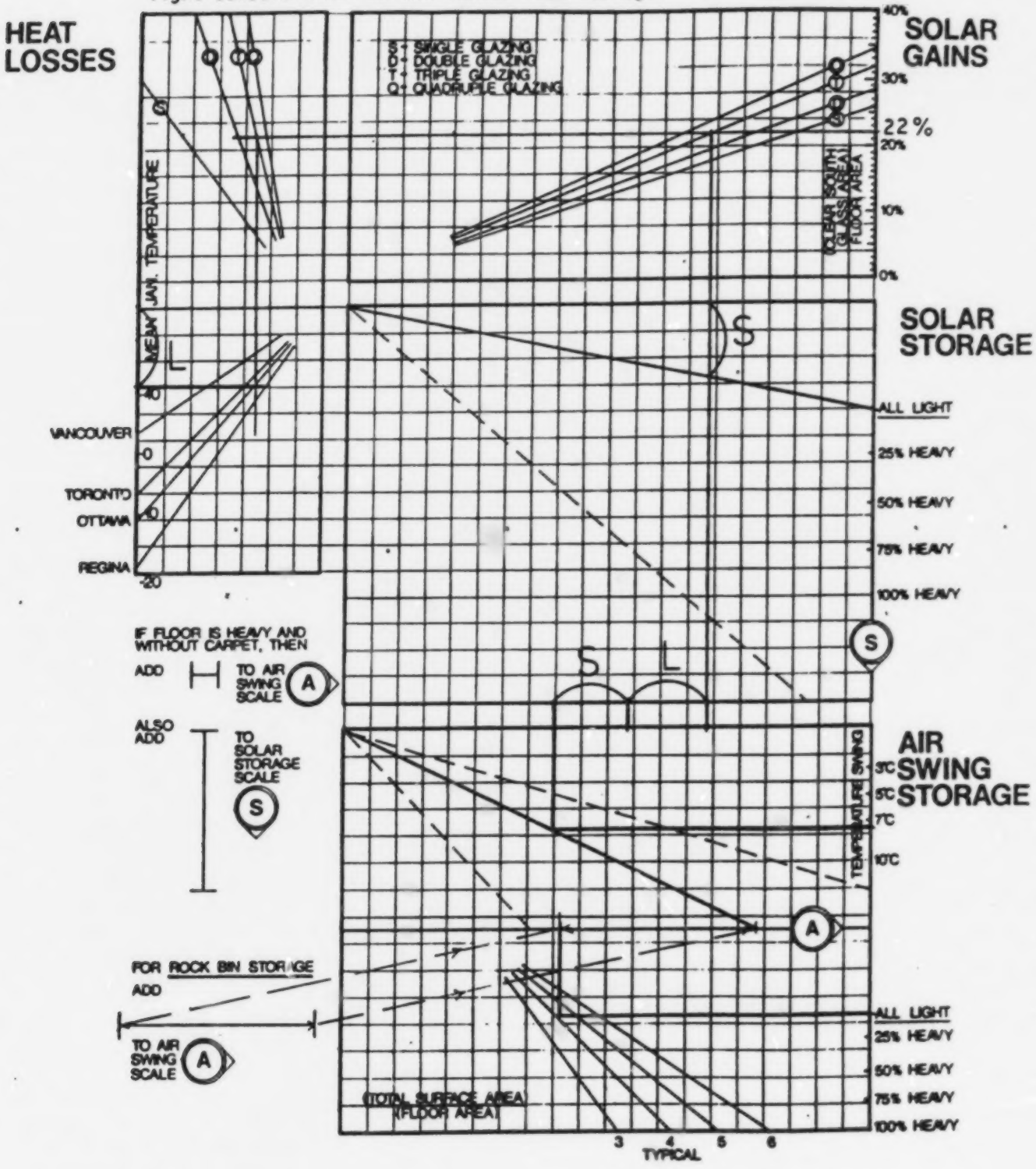


Fig.13

4. CALCULATION OF HEATING ENERGY REQUIREMENT

4.1 Outline

Calculation of the annual auxiliary heat (the purchased heating energy) involves three distinct steps:

i) Determination of the Above Grade Heat Loss Coefficient, i.e. the rate of the heat loss from the house at one degree temperature difference between indoors and outdoors, excluding the basement floor and below grade wall losses. This loss coefficient indicates the thermal quality of the skin of the house and depends on the amount of thermal insulation, air tightness and glazing type and area.

ii) Determination of the heat loss through the below grade components, i.e. basement walls and floor.

iii) Calculation of the Annual Auxiliary Heat Requirement. The results of the two preceding steps are used in this step as well as internal gains (heat from appliances, lighting and bodies of the occupants), the local degree days and the local solar gains. Solar gains and degree days are arranged as families of graphs for a specific location.

Refinements for this calculation include adjustments for:

- shading effects of overhangs, protruding walls, etc.

- thermal mass effects on the utilizability of the solar gains.

Sample calculations are provided after the description of each phase of the Heating Energy Requirement Calculation. Sample calculations illustrate the use of the graphical methods with an actual example. Plans, section and other data of the house used in the sample calculations can be found in the foldout of Appendix K.

4.2 Graphical Calculation of the Above Grade Heat Loss Coefficient

Any annual heating energy calculation method requires that the heat loss coefficient of the structure be determined. The graphical "Above Grade Heat Loss" calculation is particularly suited for the preliminary design stage as it requires only the overall house dimensions, R-Values and glazing percentage as input values, all known to the designer before the structure is committed to drawings.

The calculation sequence is indicated on the "Above Grade Heat Loss" graph (Fig. 14 on p. 27). Enter at the upper left hand corner with the house width and length. Continue with the wall R-Value, basement above grade R-Value, roof R-Value and the infiltration rate exressed as the number of air changes per hour. Refer to Apeendix A for recommended infiltration rates. Next enter the graph at the lower left hand corner with glazing type and wall R-Value again. Continue to the right with the gross (masonry opening) glass area expressed as a percentage of the floor area (excluding basement) and continue up to the Result Square. The Above Grade Heat Loss coefficient per unit of floor area is given at the intersection of the vertical line from the Glass Loss square and the horizontal line from the Infiltration Loss square.

If special low loss glazings or night shutters are used, the glass R-Value rather than the glass type can be the entry point to the Glass Loss square. To adjust for night shutters mark the two R-Values, without shutters and with shutters, on the lower scale of the square. If shutters are on 50% of the time then use the point halfway between the two marks as the entry point up to the diagonal lines.

The graphical method is designed for a two storey structure. Floor to floor height is taken to be 2.5m and the basement above grade height is taken as .5m (10% of the overall wall height). There is also an allowance for infiltration into the basement at half the rate of that into the above grade floors.

If the house is split level type or the two floors are of unequal area, it may be necessary to calculate the wall to floor ratio manually and to enter the graph at the left hand side of the Wall Loss square, rather than at the House Proportions square. The floor area must not include the basement since roof area and infiltration volume are calculated automatically on this basis. Roof loss for a single floor bungalow, when compared to a two floor house, is twice as high and this can be accounted for by dividing the roof R-Value by two, as noted on the graph. Similarly, for a three storey house the roof R-Value should be multiplied by 3 and divided by 2.

If only the glazing area is changed then it is only necessary to draw a new vertical line from the Glass Loss square up to the Result square. If wall R-Value is changed, then most of the calculation has to be redone.

ABOVE GRADE HEAT LOSS

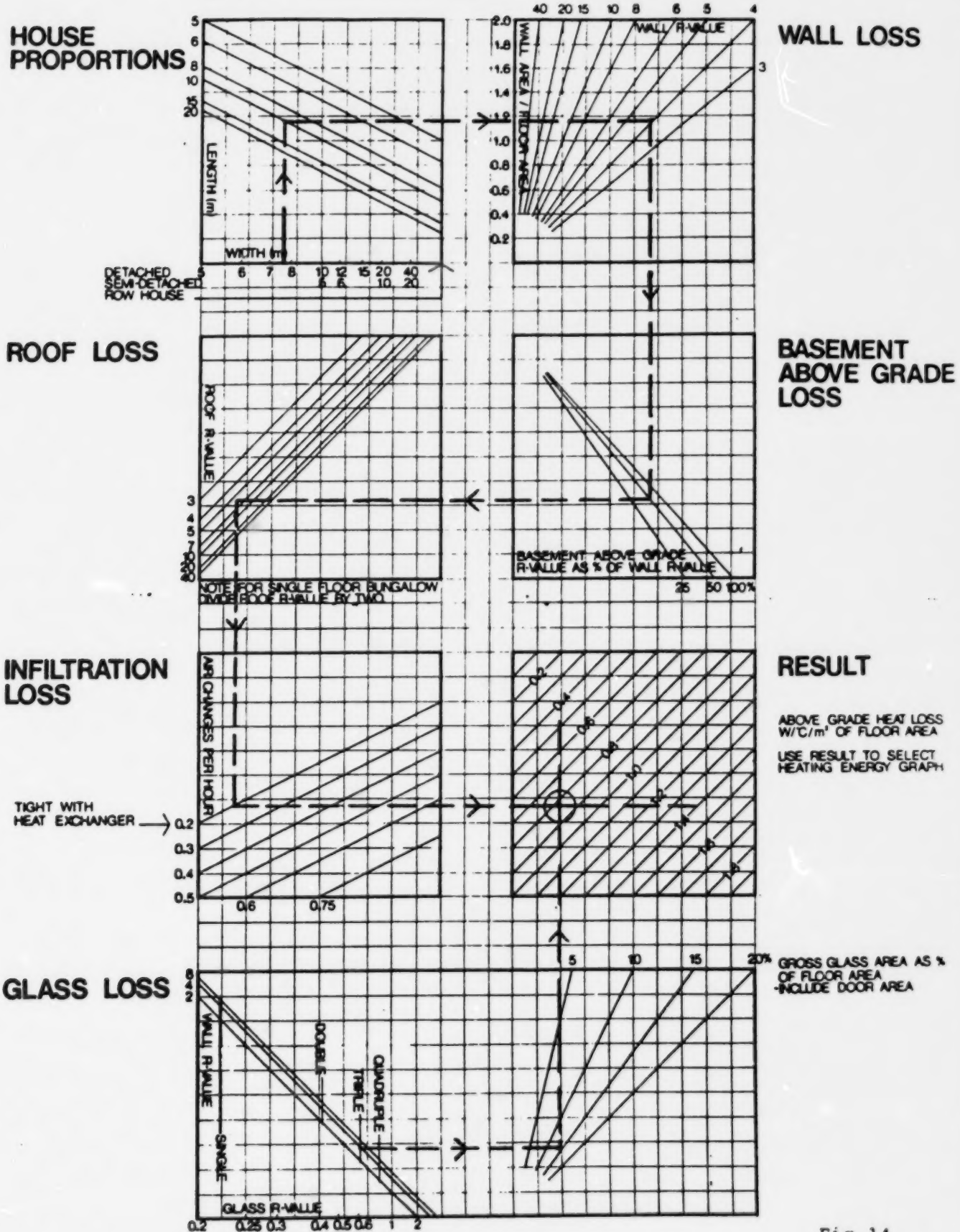
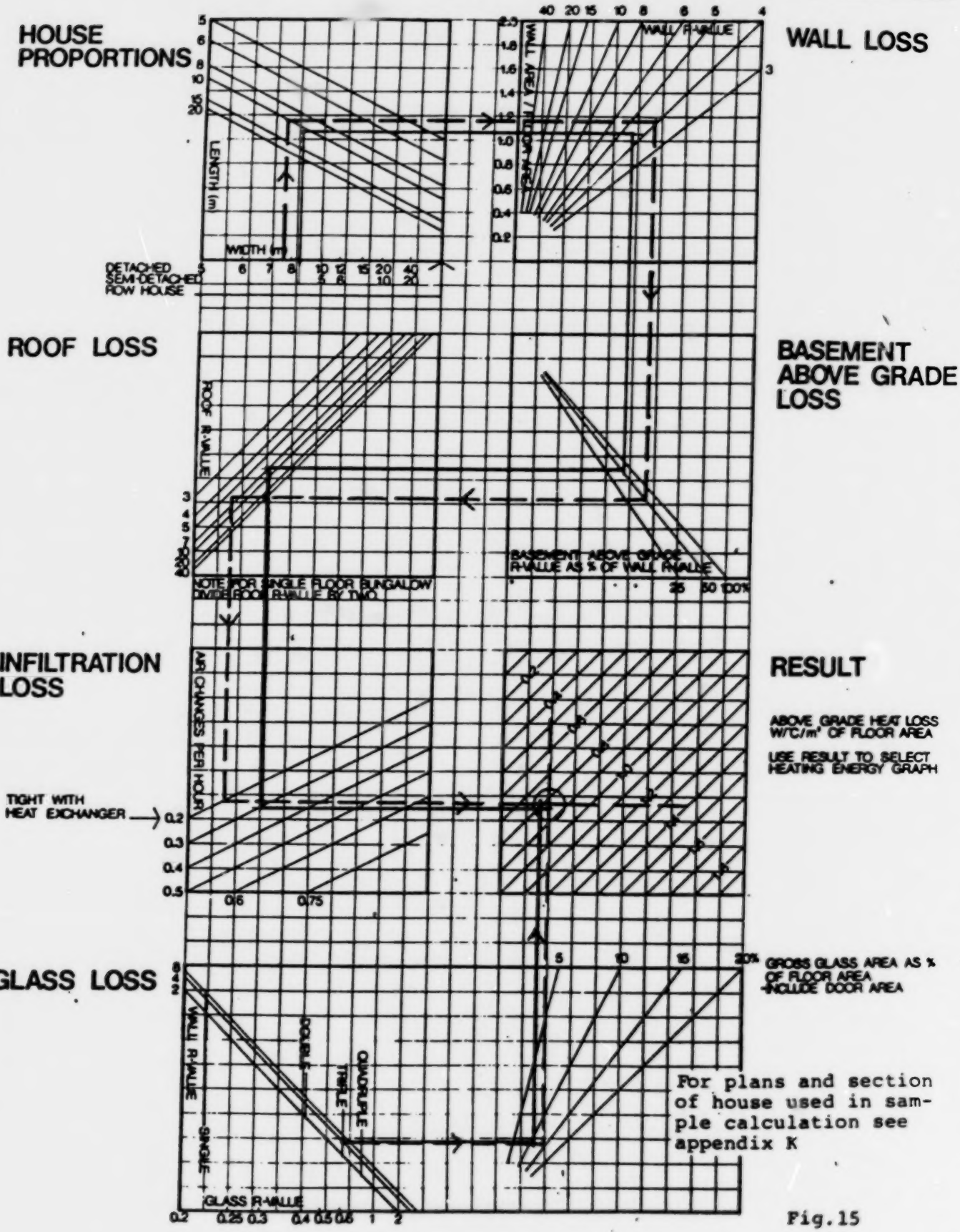


Fig.14

ABOVE GRADE HEAT LOSS

SAMPLE CALCULATION



For plans and section of house used in sample calculation see appendix K

Fig.15

4.3 Graphical Calculation of the Below Grade Losses

The step by step calculation procedure is outlined in the calculation forms titled BASEMENT FLOOR LOSS and BASEMENT WALL BELOW GRADE LOSS. Basements losses vary slowly from month to month. Due to the delay caused by the mass of the earth the highest losses occur in late winter and early spring.

In order to avoid the complication of the month-to-month variation in the basement losses the calculation is arranged to give the correct result if the heating season is 7 months long. If the heating season is 5 months long then the average loss will be higher. One can adjust for this by changing the number inside the brackets of the basement wall loss calculation from 5.5 to 7.8. The correct adjustment for a 9 month long heating season is to change this number to 3.15. The shorter heating seasons may occur with very well insulated passive solar housing. Length of the heating season is determined in the subsequent graphical heating energy calculations. The month-to-month fluctuation of the basement floor loss is so slight that it can be safely neglected in the present preliminary design calculations.

The design graph covers the most common method for the installation of the insulation. Refer to Appendix C for more detailed calculation methods.

BASEMENT FLOOR LOSS

HOUSE FLOOR AREA — m2 (22)

BASEMENT FLOOR AREA
Include vertical area at change in floor level. — m2 (30)

BASEMENT FLOOR INSULATION R-VALUE
(Zero (0) if no insulation) — Cm2/W (31)

MEAN ANNUAL TEMPERATURE DIFFERENCE

BASEMENT SPACE TEMPERATURE — C
MINUS
ANNUAL MEAN OUTSIDE AIR TEMPERATURE — C
= C (32)

Vancouver 9.8 Regina 2.2 Ottawa 6.0
For other locations, obtain from Weather Data Tables.

BASEMENT FLOOR LOSS PER UNIT OF HOUSE FLOOR AREA

$$\frac{(30) \times (32) \times 2.62}{\left((31) + 3.6\right) \times (22)} =$$ MJ/month/m2 (33)

BASEMENT WALL BELOW GRADE LOSS

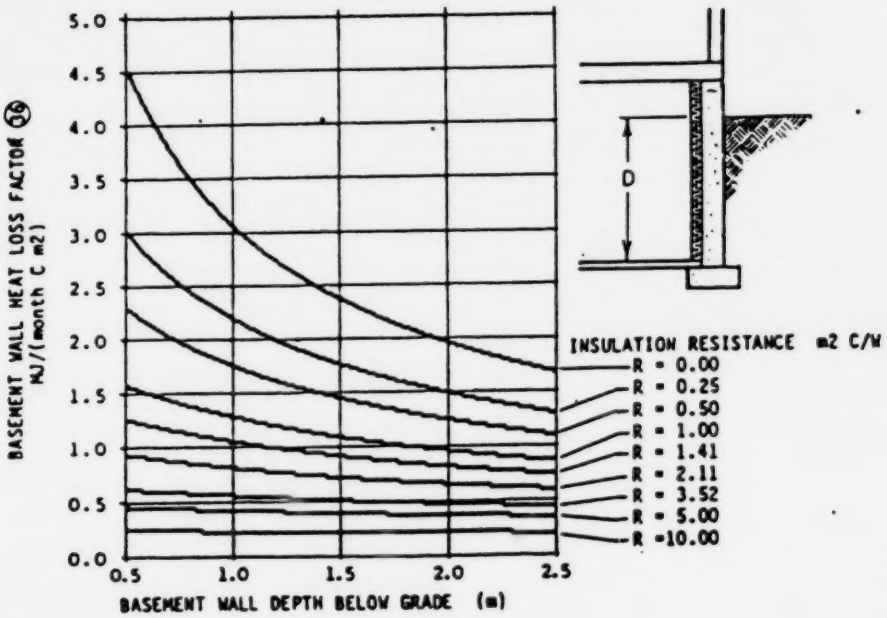


Fig.16

BASEMENT WALL HEAT LOSS FACTOR
From graph above. — MJ/monthCm2 (36)

BASEMENT WALL BELOW GRADE AREA — m2 (37)

BASEMENT WALL LOSS PER UNIT OF HOUSE FLOOR AREA

$$\left(5.5 + (32)\right) \times (36) \times (37) / (22) =$$ MJ/month/m2 (38)

BASEMENT FLOOR LOSS

HOUSE FLOOR AREA — 197 m2 (23)

BASEMENT FLOOR AREA
Include vertical area at change in floor level. — 98.3 m2 (30)

BASEMENT FLOOR INSULATION R-VALUE
(Zero (0) if no insulation) — 0 Cm2/W (31)

MEAN ANNUAL TEMPERATURE DIFFERENCE

BASEMENT SPACE TEMPERATURE	20 C	MINUS
ANNUAL MEAN OUTSIDE AIR TEMPERATURE	6 C	= 14 C (32)

Vancouver 9.8 Regina 2.2 Ottawa 6.0
For other locations, obtain from Weather Data Tables.

BASEMENT FLOOR LOSS PER UNIT OF HOUSE FLOOR AREA

$$\frac{983\ (30) \times 14\ (32) \times 2.62}{(0\ (31) + 3.6) \times 197\ (23)} = 5.08 \text{ MJ/month/m2 (33)}$$

BASEMENT WALL BELOW GRADE LOSS

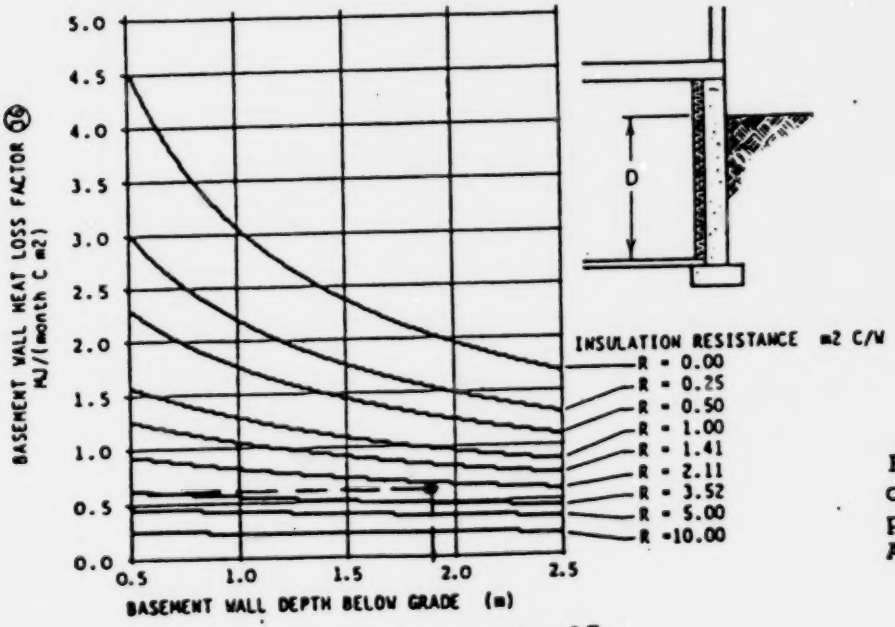


Fig.17

For plans and section of house used in sample calculation see Appendix K

BASEMENT WALL HEAT LOSS FACTOR
From graph above. — 0.6 MJ/monthCm2 (36)

BASEMENT WALL BELOW GRADE AREA

$$(11.7 + 8.4) \times 2 \times 1.9 = 76.4 \text{ m2 (37)}$$

BASEMENT WALL LOSS PER UNIT OF HOUSE FLOOR AREA

$$(5.5 + 14\ (32)) \times 0.6\ (36) \times 76.4\ (37) / 197\ (23) = 4.54 \text{ MJ/month/m2 (38)}$$

4.4 Graphical Calculation of the Auxiliary Heat Requirement

Engergy performance of a structure is best judged by its Annual Auxiliary Heat Requirement (the Annual Purchased Heating Energy). The present graphical method is an adaptation of the Degree Day methodology.

The family of Heating Energy Graphs provided in Appendices F, G and H is a plot of monthly degree-days for a specific location, pre-multiplied by a range of likely Above Grade Heat Loss coefficients. The area under such graph is equal to the Annual Auxiliary Heat Requirement, before any allowance for basement losses, internal gains and solar gains. The graphs are plotted to such a scale that the area under the graph is obtained by using a 1:100 scale (or a millimetre scale) and adding up the distances along the vertical "month" lines. Each millimetre represents a MJ per unit of floor area. There are nine month lines, starting with September and ending with May. The basement losses are accounted for by dropping the baseline (1 mm for each $MJ/month/m^2$). To account for the internal gains the baseline is raised, thus reducing the area under the graph.

To account for the solar gains, another set of graphs is prepared for each location. The Solar Gains Graphs that are provided in Appendices F, G and H, represent the solar gains through south oriented double glazing, pre-multiplied by a range of likely glass areas. The Solar Gains Graphs are overlaid over the Heating Energy Graphs, with the base of the solar graph located at the base of the heating graph as shifted by the basement losses and the internal gains.

The area remaining between the appropriate Solar Gains curve and the Heating Energy curve is the net Annual Auxiliary Heat Requirement. During preliminary design it may not be necessary to determine the numerical value of the area as the effect of several design alternates on the Auxiliary Heat area can be judged by eye. The heating season length is the left-to-right length of the Auxiliary Heat area. The refinements incorporating shading and mass effects are discussed later. Omission of such refinements is quite appropriate for the "first cut" preliminary design.

The step by step procedure is as follows:

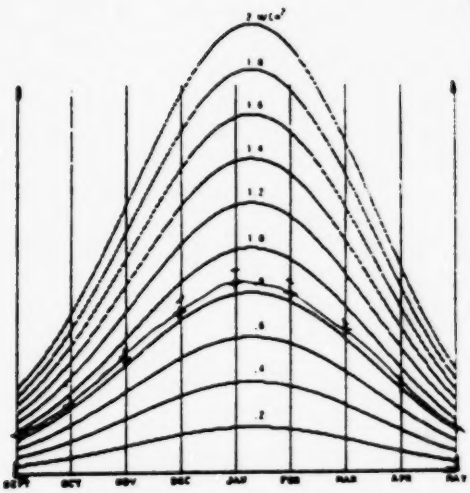


Fig.18

1. Put a sheet of tracing paper over the Heating Energy Graph for your location. Draw in the baseline and the two sidelines. Select the appropriate Heating Energy curve as determined $W/C/m^2$ from either graphical or manual Above Grade Heat Loss calculation. Mark in small crosses at each vertical month line, while following the selected curve. If your Above Grade Heat Loss falls between two curves, then estimate the proper position of the crosses by eye. Next draw a curve connecting all the crosses. Accuracy of this curve is not important as all measurements will be to the monthly cross marks.

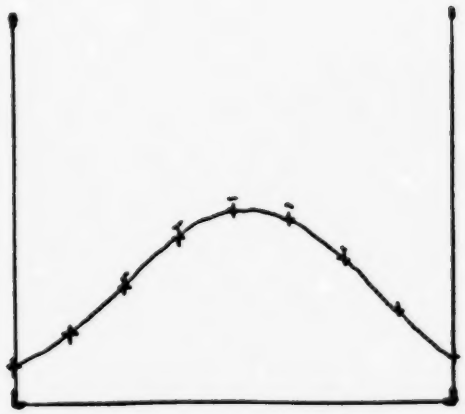


Fig.19

When you remove the tracing paper the result will look like that shown at left.

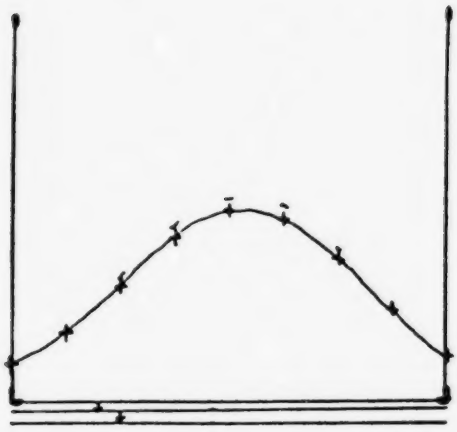


Fig.20

2. Using the 1:100 scale or millimetre scale (1mm for each MJ/month/m2) mark down from the baseline the two basement losses - basement floor and basement wall below grade (basement wall above grade loss is included in the Above Grade Heating Energy curve). Your graph on the tracing paper now includes all of the gross heat losses and looks like that at the left.

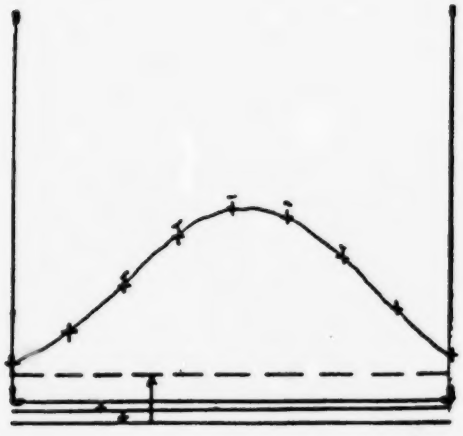


Fig.21

3. Again using the scale, mark up from the lowest basement line the internal gains. Typical internal gains rate is 17 MJ/m^2/month. See Appendix B for a discussion of how this rate is determined. Therfore mark up 17mm from the lowest basement line and draw in a dashed line so that it will stand out.

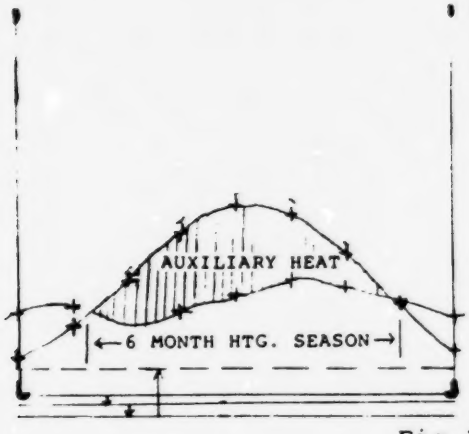


Fig.22

4. Put the sheet of tracing paper with the partially completed graph over the Solar Gains Graph for your location. Line up the dashed base line with the base line of the Solar Gains Graph underneath. Select the appropriate curve corresponding to the area of clear south glazing expressed as percentage of the total house floor area (excluding basement). This must be the same floor area as that used in the Above Grade Heat Loss calculation and the Basement Loss calculation, i.e. Line No. 22. Note that the graphical Above Grade Heat Loss calculation uses floor area that excludes the basement floor area.

The Solar Gains Graphs are correct for double glazing. If triple glazing is being used then multiply the glass percentage by .91 and then choose the solar gain curve. Correction factors for quadruple glazing and single glazing are .83 and 1.1 respectively. Using a similar procedure as before mark in crosses at month lines and draw the solar curve through the crosses. This completes the "first cut" graphical calculation. Repeat steps 1 to 4 for a design alternate that you wish to consider, compare the enclosed areas visually and note the change in the Auxiliary Heat Requirement. The alternate calculation may be done on the same sheet of tracing paper, or on a separate sheet and the results compared by overlaying of the two sheets.

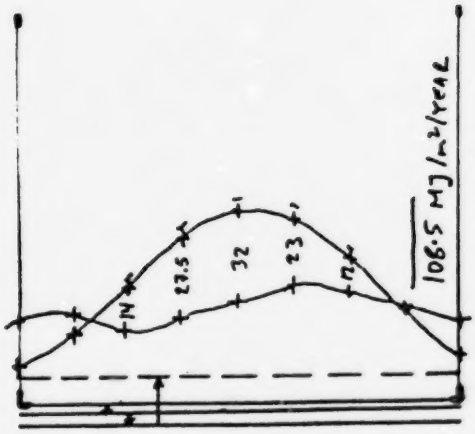


Fig.23

5. To obtain numerical results measure the distance between the Heating Energy cross and the Solar Gains cross along each month line. Write down each measurement and then add them together. The sum gives the net Annual Auxiliary Heat requirement per unit of floor area. Multiply by floor area to get the Auxiliary Heat in MJ/year.

SAMPLE CALCULATION

For plans and section of house used in sample calculations see Appendix K

ABOVE GRADE HEAT LOSS COEFFICIENT .8 W/C m²

BASEMENT FLOOR LOSS 5 MJ/m²/MONTH

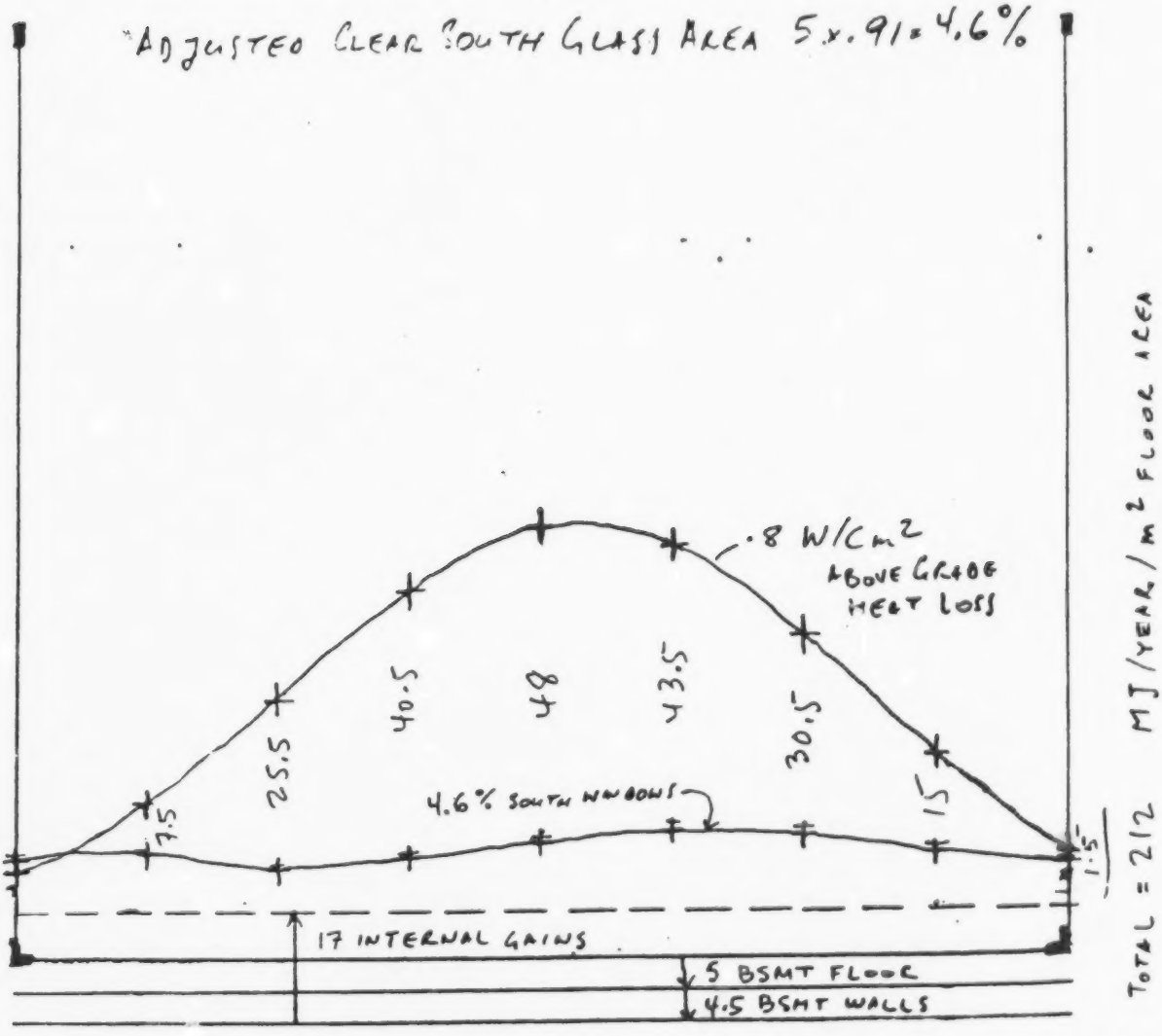
BASEMENT WALL LOSS 4.5 MJ/m²/MONTH

INTERNAL GAINS 17 MJ/m²/MONTH

SOUTH GLASS (CLEAR) $\frac{9.95}{197} = 5\%$

TRIPLE GLAZING ADJUSTMENT .91

ADJUSTED CLEAR SOUTH GLASS AREA 5 x .91 = 4.6%



Note: See also sample calculations on pages 54 and 55 for the same sample house, but with twice as much south glass area.

Fig.24

4.5 Shading Effects

The importance of the effects of shading on the winter thermal performance can be better appreciated by considering one of the basic principles of passive solar heating. In active solar heating one can shut off the losses during the periods of inadequate solar gains by simply stopping the pump or the fan of the system. This cannot be done with a passive system. The net useful passive solar heating effect is the difference between the large intermittent solar gains and the large continuous heat losses through the solar aperture. Therefore, obstructing say 20% of the solar gains by shading results in a much greater reduction of the net passive solar heating effect. The situation is akin to a business that has a large income and large expenses resulting in a profit that is say 10% of its gross income. Cutting the income by 20% without reducing the expenses can bring about a bankruptcy. Similarly, shaded south glazing can change from a "net gainer" to a "net loser" of energy.

Shading may result from:

- Overhangs
- Protruding Walls Near Windows
- Recessing of Windows
- Nearby Tall Objects

The solar gains consist of three main components: beam radiation gain, sky diffuse radiation gain and ground reflected radiation gain. During sunny days in winter beam radiation is the predominant gain. During overcast days there is no beam radiation and all of the solar gains consist of sky diffuse and ground reflected gains. The different types of shading affect the three components differently e.g. an overhang does not change the ground reflected radiation gain (unless the underside of such an overhang is light coloured and would thus enhance the reflected gain by re-reflection). The calculation of the shading effects is difficult because even long term average proportions between the three solar gain components vary between locations substantially. The position of the sun in the sky and therefore the orientation of the solar beam is different every hour and every day of the year. Thus, the beam radiation shading changes every hour, from day to day and from latitude to latitude.

For the more complex cases, e.g. overhang, shading effects are presented in the form of monthly graphs for a specific location. Such graphs are derived from hour-by-hour computer calculations utilizing the local weather data. The Monthly Shading Graphs can be used to obtain the optimum proportions of the shading device, i.e. to achieve maximum shading in summer and minimum shading in winter as discussed later. The Monthly Shading Graphs can be used also to adjust down the solar gains on the Solar Gains Graph as required to allow for the monthly shading effects. This procedure is accurate, but requires considerable effort and therefore is not suited for preliminary

design. To make the necessary shading adjustments in the Heating Energy Requirement calculation it is preferable to use the two simpler shading effect presentation methods discussed later: the Seasonal Shading Graphs and the special Solar Gains with Overhang graphs that include the shading corrections.

In the following articles the shading effects of overhangs and protruding walls near south windows are discussed. Effects of window recessing are discussed in Appendix D. Shading by nearby tall objects is discussed in Appendix E.

4.6 Overhang Shading

The purpose of the overhang is to reduce the solar gains in summer. The net effect of the overhang on summer solar gains is not as great as might appear from the observation that the south window is fully shaded by the overhang in summer. The reflection properties of vertical glazing are such that with high summer sun the glass itself excludes most of the beam radiation gains. While in January the beam radiation gains may constitute 82% of the total solar gains (for Ottawa), in July they amount to only 32% for double glazing without an overhang. The remainder is made up of 34% sky diffuse and 34% ground reflected solar gains. Therefore, a typical overhang cannot eliminate more than some 40% of the summer solar gains.

As discussed previously, the overhang may increase the ground reflected radiation gains by the amount re-reflected from the underside of the overhang. It is preferable therefore to use dark colours for the underside of the overhang, or to use open inclined slat type or sloping solid overhangs that do not "see" much of the ground reflected radiation. The optimum thermal solution is to use retractable or removable overhangs or awnings that do not obstruct any of the solar gains during the heating season and at the same time can provide greater shading during the summer than the compromise solution of the fixed overhang.

Presentation of the seasonal and monthly fixed overhang shading effects is complicated by the fact that the overhang is a function of three dimensions:

- Overhang Length
- Window Height
- Windowhead Dimension (Vertical distance from the top of the the window to the tip of the overhang.)

The shading effect is determined by the proportions of these three dimensions. Good overhang design requires that the overhang be much wider than the window. It is assumed that this rule is followed and therefore the added complication of the overhang width can be neglected.

The Monthly and Seasonal Shading Graphs provided in Appendices F, G and H, indicate the amount of shading for each element of the south wall and window. It is necessary to mark in the window in the correct proportion to the fixed overhang length of the graph. The procedure is to mark in two lines on the section of the wall on your drawings showing the overhang and window configuration to any scale. Draw one line from the tip of the overhang to the top of the window and another from the tip of the overhang to the bottom of the window. Next measure the angle of each of the lines from the horizontal. Draw in two similar lines from the tip of the overhang on the shading graph, using the same angles. The window is then correctly positioned on the vertical line of the graph. Estimate the average height of the appropriate curve over the window dimension to obtain the average shaded percentage. Average shaded percentage can be calculated with the help of several equally spaced readings of the graph as illustrated on Fig. 27.

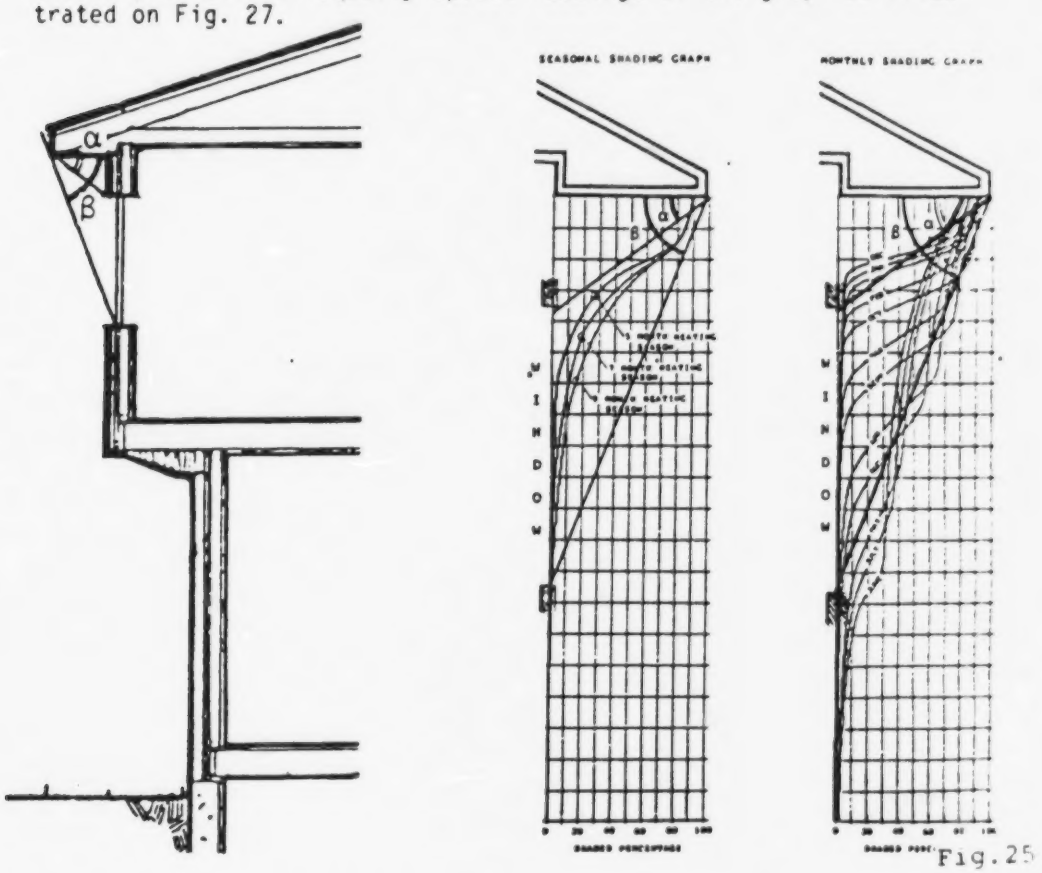


Fig. 25

This type of presentation gives an immediate visual indication of the overhang effect and allows the handling of the varying proportions of the windowhead and the window height dimensions in a simple and visual manner.

The Seasonal Shading Graphs allow a quick estimate of the seasonal effect as a function of the heating season length. The nine month heating season includes the months of September to May, the seven month season includes October to April and the five month season includes November to March.

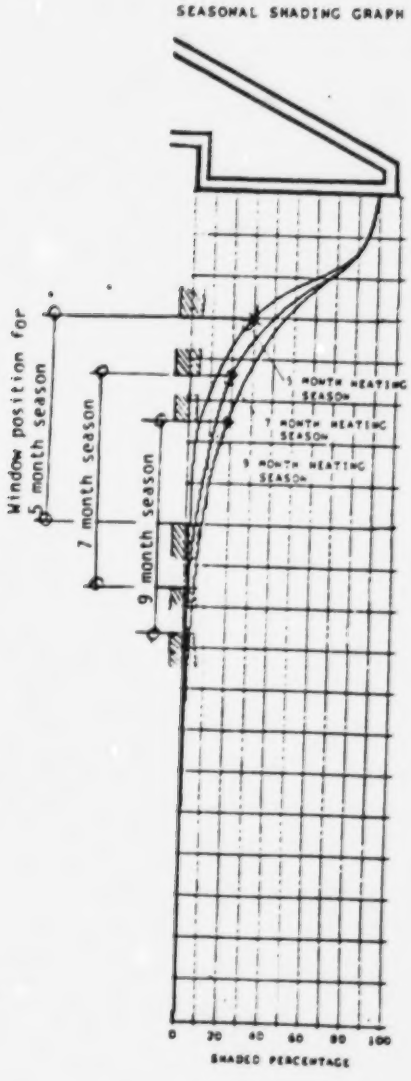
The Seasonal Shading Graph can be used to determine the window and overhang configuration that would allow not more than say 10% of the useful solar gains to be shaded out. This may be a good first cut strategy for sizing the overhang.

In the example below it is assumed that the window height and overhang length are equal. For 10% average seasonal shading in Ottawa the window head has to be as follows:

.6 of window height for 5 month heating season

.9 of window height for 7 month heating season

1.1 of window height for 9 month heating season.



Window positions for 10% shaded percentage average over window height for various heating season lengths. The example is for the case where the window height is equal to the overhang length. Average shaded percentage can be estimated visually or calculated with the help of several equally spaced readings of the graph as illustrated on Fig. 27.

Fig.26

An approximate effect of shading on the energy calculations is obtained in the following manner. Read the shaded percentage on the Seasonal Shading Graph and multiply the south glazing area percentage by

1 - (Shaded Percentage) / 100

Select the Solar Gains curve that corresponds to the so corrected south glazing area percentage. The larger area between the lowered Solar Gains curve and the original Heating Energy curve now represents the Auxiliary Heating Requirement corrected for the shading effects.

O T T A W A

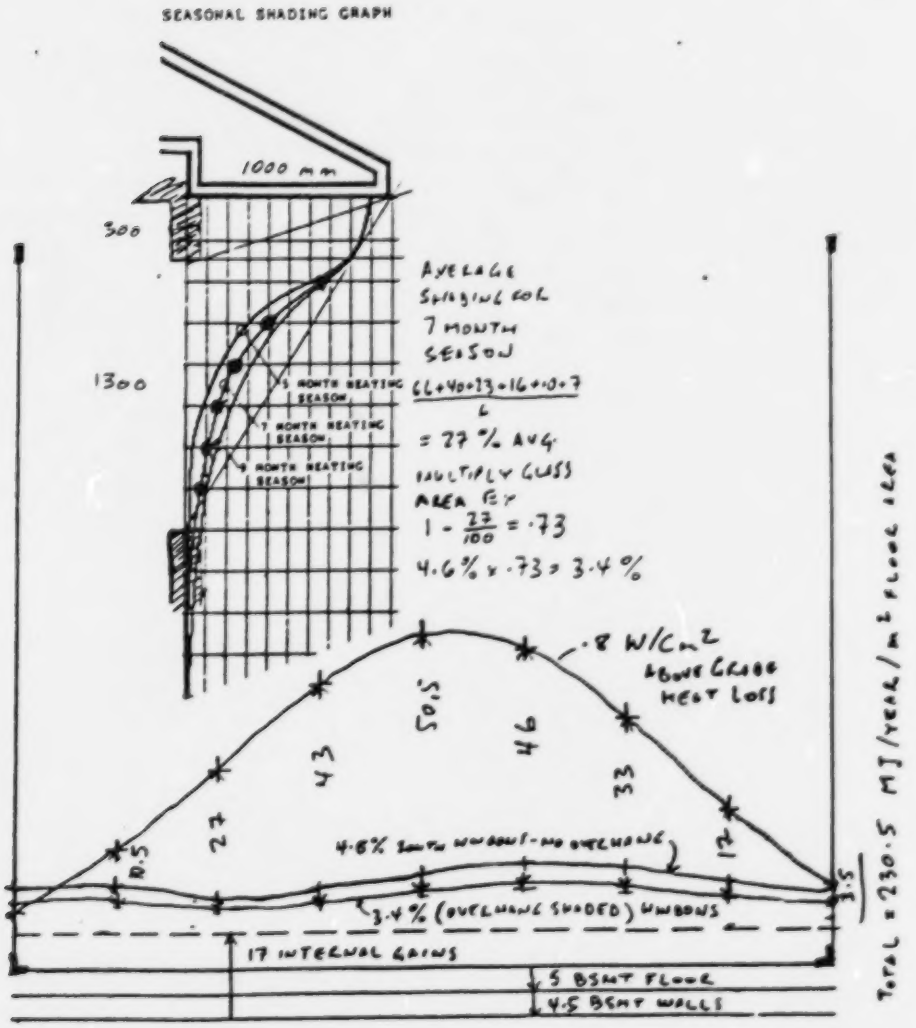


Fig.27

A more accurate and quicker calculation procedure is to use the special Solar Gains with Overhang graphs that incorporate the shading resulting with three typical overhang configurations. These can be found in Appendices F, G and H. Simply use the special Solar Gains with Overhang graph in place of the normal graph in the appropriate calculation step. If it desired to interpolate for a specific overhang configuration that is different from the three typical cases, then trace all three cases plus the normal (no overhang) case onto your calculation tracing and use judgement to visually determine, and mark in, the "in-between" curve for your specific case. This is illustrated in the following figure.

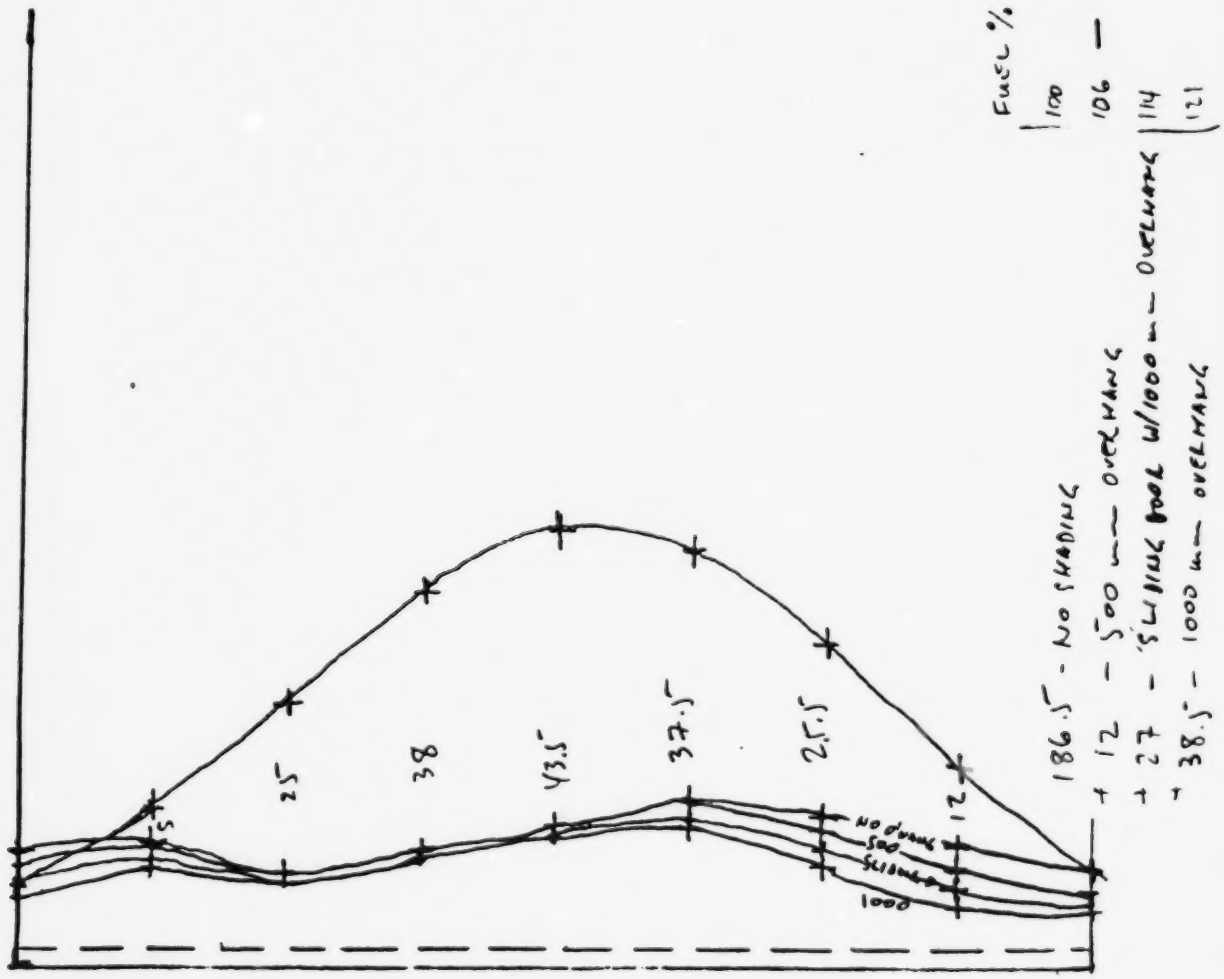
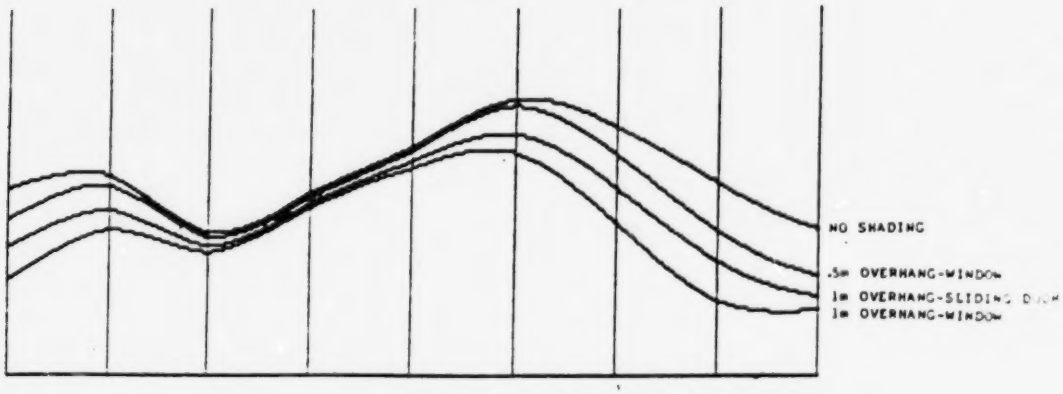
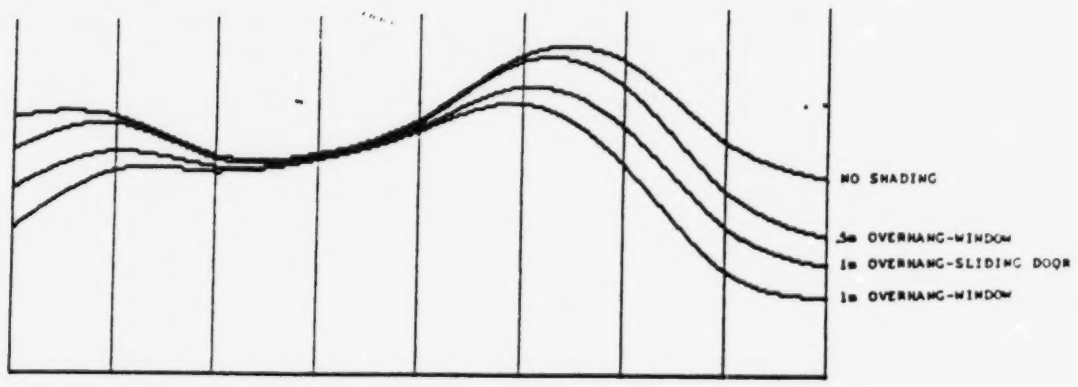


Fig.28

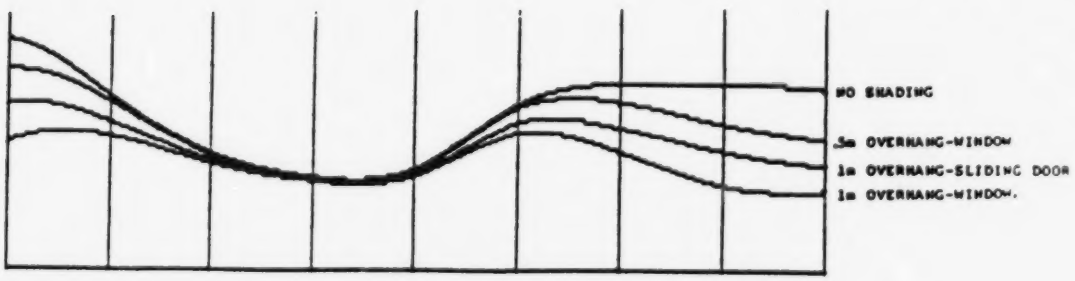
The varation of the shading effect during the heating season with several typical overhang configurations and in different locations is illustrated in the following solar gains graphs.



OTTAWA SOLAR WITH OVERHANG



REGINA SOLAR WITH OVERHANG

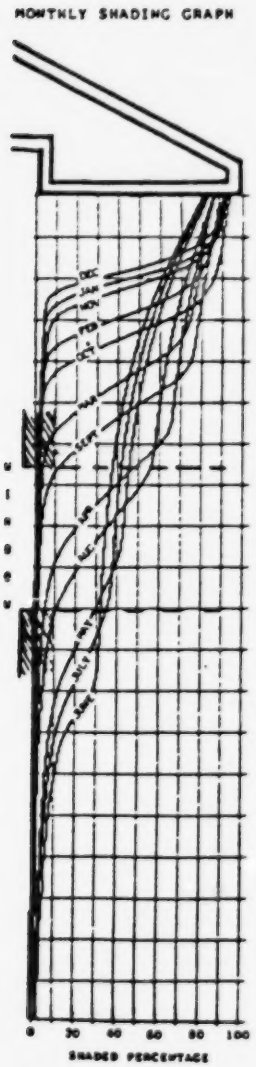


VANCOUVER SOLAR WITH OVERHANG

Fig.29

Note that the shoulder months, particularly the spring months, are affected much more by the shading than the early winter months.

The monthly Shading Graph can be used to determine the optimum overhang configuration. Example below shows window, overhang and windowhead proportions for minimum shading in winter months and maximum shading in summer months. The months of May and August have opposing requirements and generally cannot be accomodated by a fixed overhang because of their sequence on the shading graph. The ideal overhang and windowhead proportions may be difficult to accomodate in a practical design. The windowhead would have to be about twice the height of the window. The graph indicates that an overhang without a windowhead is a "no-no" in passive design. The top part of a window without a windowhead never gets any solar gains, yet loses heat continuously.



Note: Best proportions for window, windowhead and overhang for this location. No shading September to March. Full shading May, June, July. Partial shading April and August. Less shading during April and more shading during August would be desirable, but cannot be obtained with a fixed overhang.

Fig.30

SAMPLE CALCULATION

For plans and section of house used in sample calculations see Appendix K

ABOVE GRADE HEAT LOSS COEFFICIENT .8 W/Cm^2

BASEMENT FLOOR LOSS 5 MJ/m^2/MONTH

BASEMENT WALL LOSS 4.5 MJ/m^2/MONTH

INTERNAL GAINS 17 MJ/m^2/MONTH

SOUTH GLASS (CLEAR) $\frac{9.95}{197} = 5\%$

TRIPLE GLAZING ADJUSTMENT .91

ADJUSTED CLEAR SOUTH GLASS AREA 5 x .91 = 4.6%

ADD SHADING WITH

1000 mm OVERHANG

300 mm WINDOWHEAD

1300 mm WINDOW HEIGHT

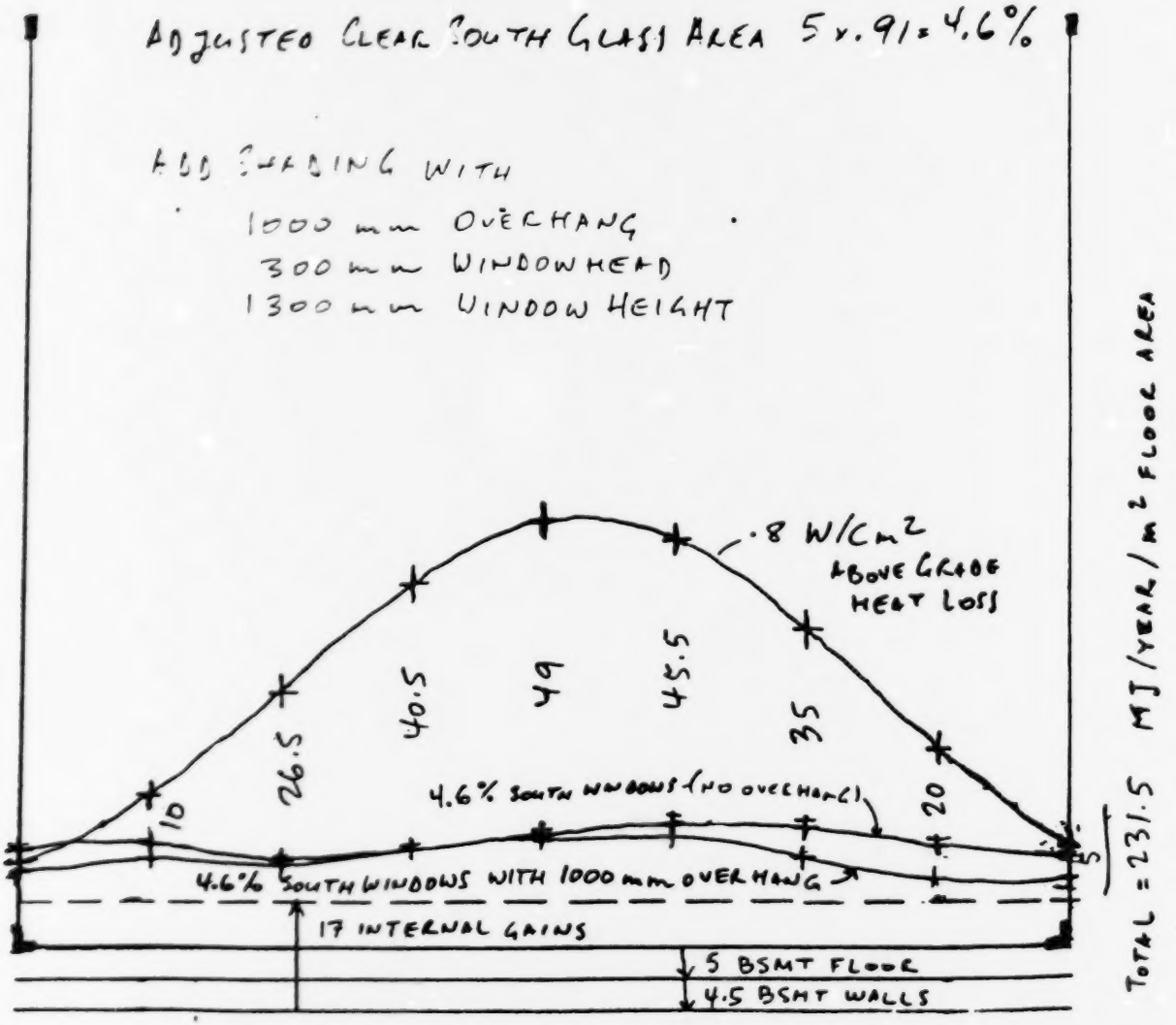


Fig.31

4.7 Protruding Wall Shading

A fairly common case of shading is that of an adjacent wall protruding out at right angle to the window (e.g. attached garage). This shading affects all three of the solar gain components: beam, sky diffuse and ground reflected radiation. If such a wall is long and is very close to the window it will shade out 50% of the solar gains.

The design graph on p. 48 (Fig. 33) gives the factor to be applied to the solar gains to account for the shading by a protruding wall near a window. The window is located on the graph with the help of a protractor in a similar manner to the graphs for the overhang. Although the shading does in fact vary with latitude and the time of the year, the variation is less than for the overhang shading. In order to simplify the procedure an average design curve is given.

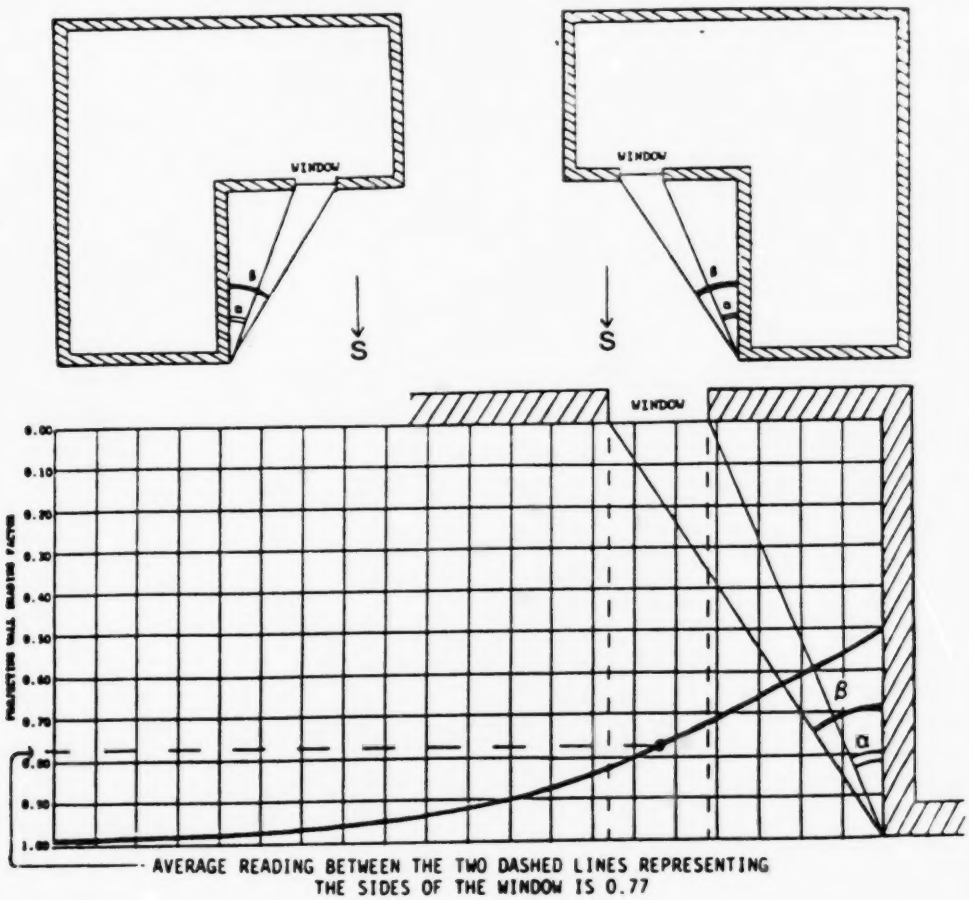


Fig.32

PROTRUDING WALL SHADING GRAPH

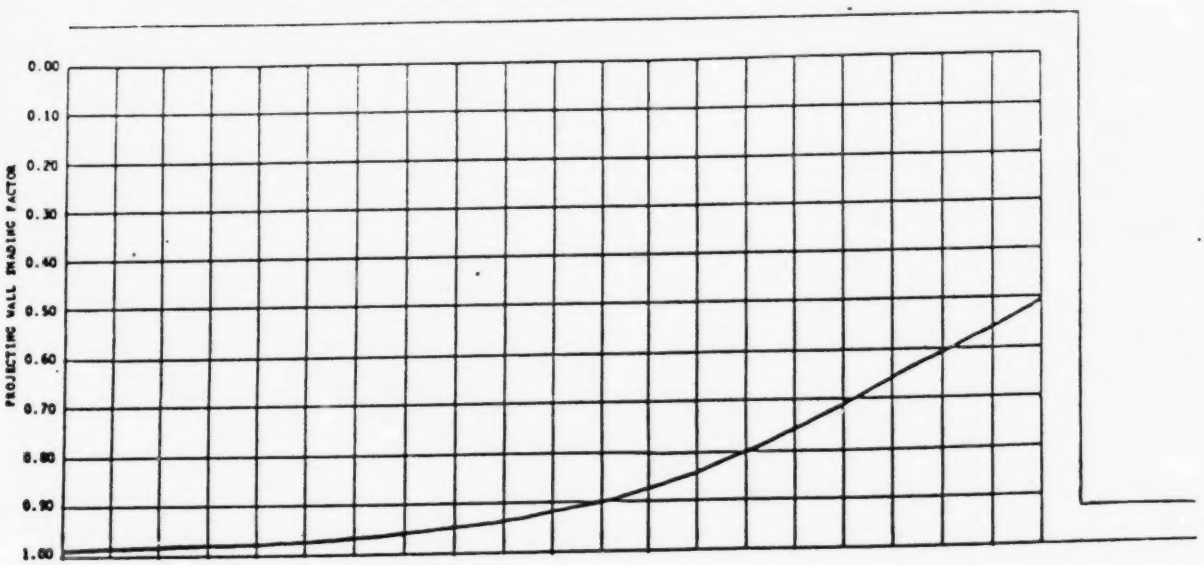
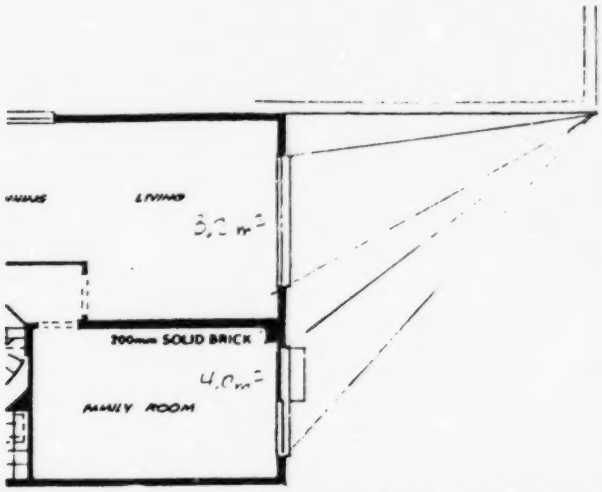
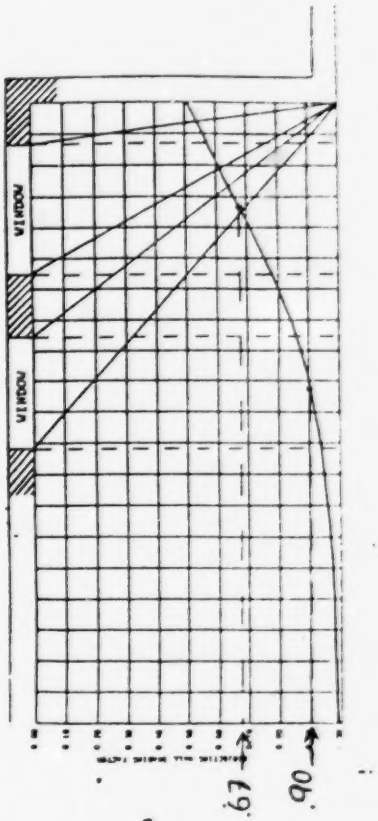


Fig.33

SAMPLE CALCULATION





For plans and section of house used in sample calculations see Appendix K

Assume that the house used in sample calculations has a protruding wall at the lower floor windows as indicated on the sketch above. Clear glass area adjusted for shading becomes:

Glass Area = 3.2 x .67 + 4.0 x .90 + 2.75 = 8.33m²

Glass percentage including triple glazing adjustment = 8.33 x .91/197 x 100 = 3.8%

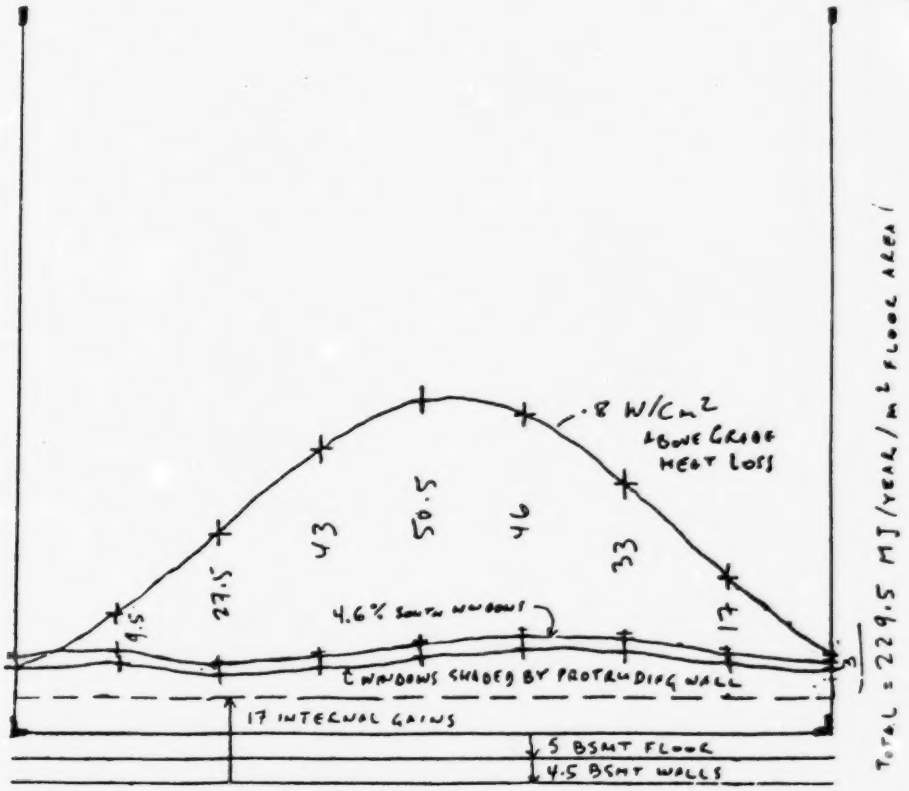


Fig.34

4.8 Adjustment for Mass Effect

The Auxiliary Heat Requirement determined without the adjustment for mass effect is correct for houses with a moderate amount of south glazing. It is also correct for houses with large glazing and large thermal mass. The correction therefore is needed for lack of mass and it reduces the useful solar gains. The Solar Gains Graph is marked downwards for months with solar gains that are close to the heat losses (months with a high solar gains to heat loss ratio). This is accomplished graphically with the help of the Mass Effect Adjustment Graph.

Put the tracing paper with the calculation results over the Mass Effect Adjustment Graph so that the dashed baseline of solar gains coincides with the baseline of the Adjustment Graph. Now slide the tracing paper to the left or to the right until the solar gain for a specific month coincides with the heavy diagonal line of the Adjustment Graph. Put a straightedge through the origin of the Adjustment Graph and the Heating Energy of the same month. At the point where the straight edge intersects the vertical scales at the right read the Solar Gain Correction Factor in the column that is appropriate for the percentage of heavy surfaces. Put a mark on the monthline at the corresponding sloping Solar Gain Correction Factor line.

MASS EFFECT ADJUSTMENT GRAPH

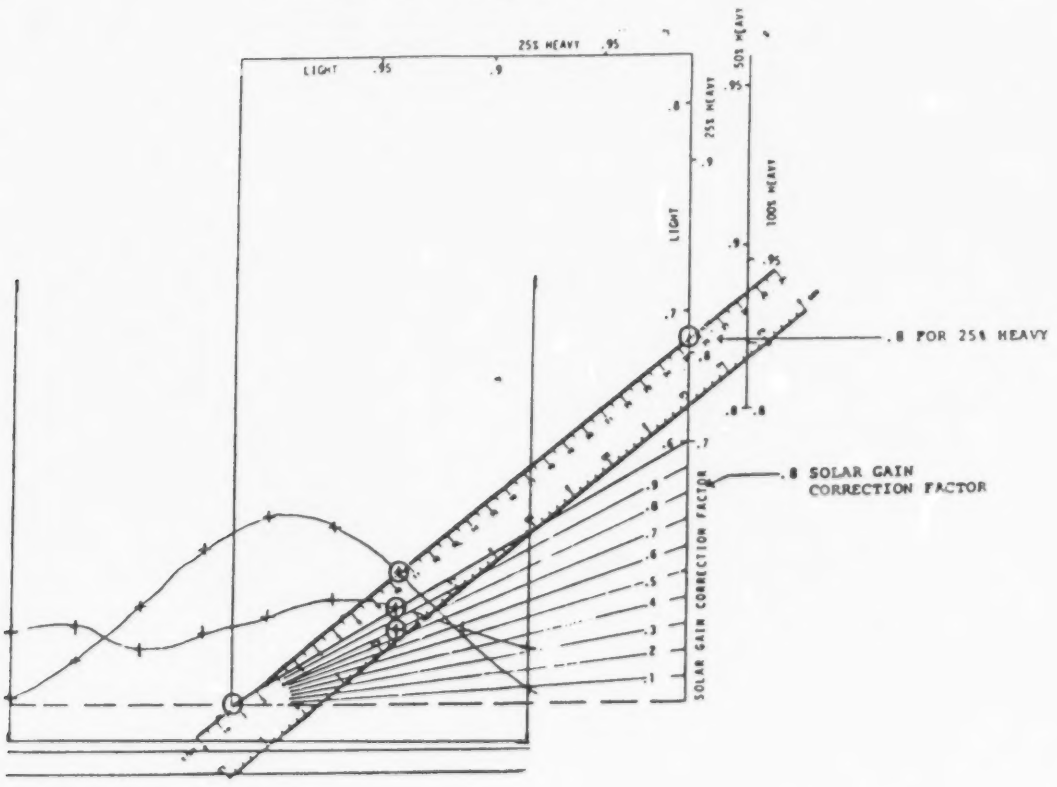


Fig.35

MASS EFFECT ADJUSTMENT GRAPH

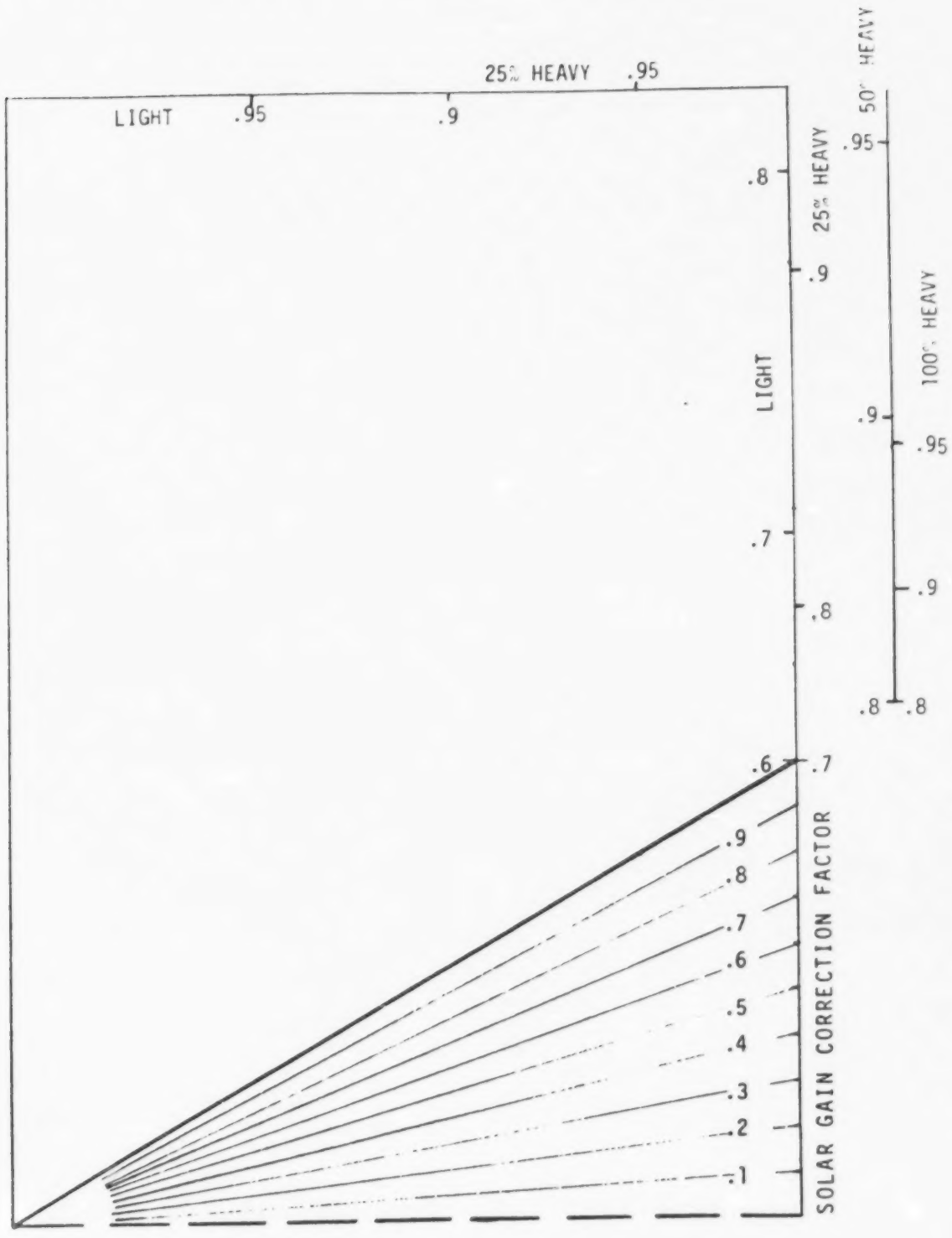


Fig.36

When this process is repeated for all the months the following corrected solar gains graph is obtained. The corrected Auxiliary Heat Requirement is the area between the Heat Energy curve and the corrected Solar Gain curve. The monthly values are measured and added up as described before.

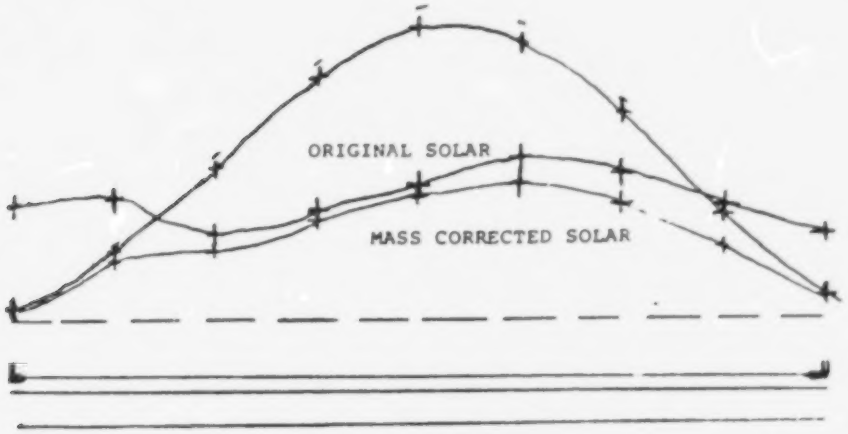


Fig.37

Note that in months where the solar curve is above the Heat Energy curve the same correction technique applies. Always line up the lower curve with the heavy diagonal, obtain the factor according to the upper curve and mark in the corrected point below the lower curve.

SAMPLE CALCULATION

For plans and section of house used in sample calculations see Appendix K

ABOVE GRADE HEAT LOSS COEFFICIENT .8 W/C m²

BASEMENT FLOOR LOSS 5 MJ/m²/MONTH

BASEMENT WALL LOSS 4.5 MJ/m²/MONTH

INTERNAL GAINS 17 MJ/m²/MONTH

SOUTH GLASS (CLEAR) $\frac{9.95}{197} = 5\%$

TRIPLE GLAZING ADJUSTMENT .91

ADJUSTED CLEAR SOUTH GLASS AREA 5 x .91 = 4.6%

ADJUSTED FOR MASS EFFECTS

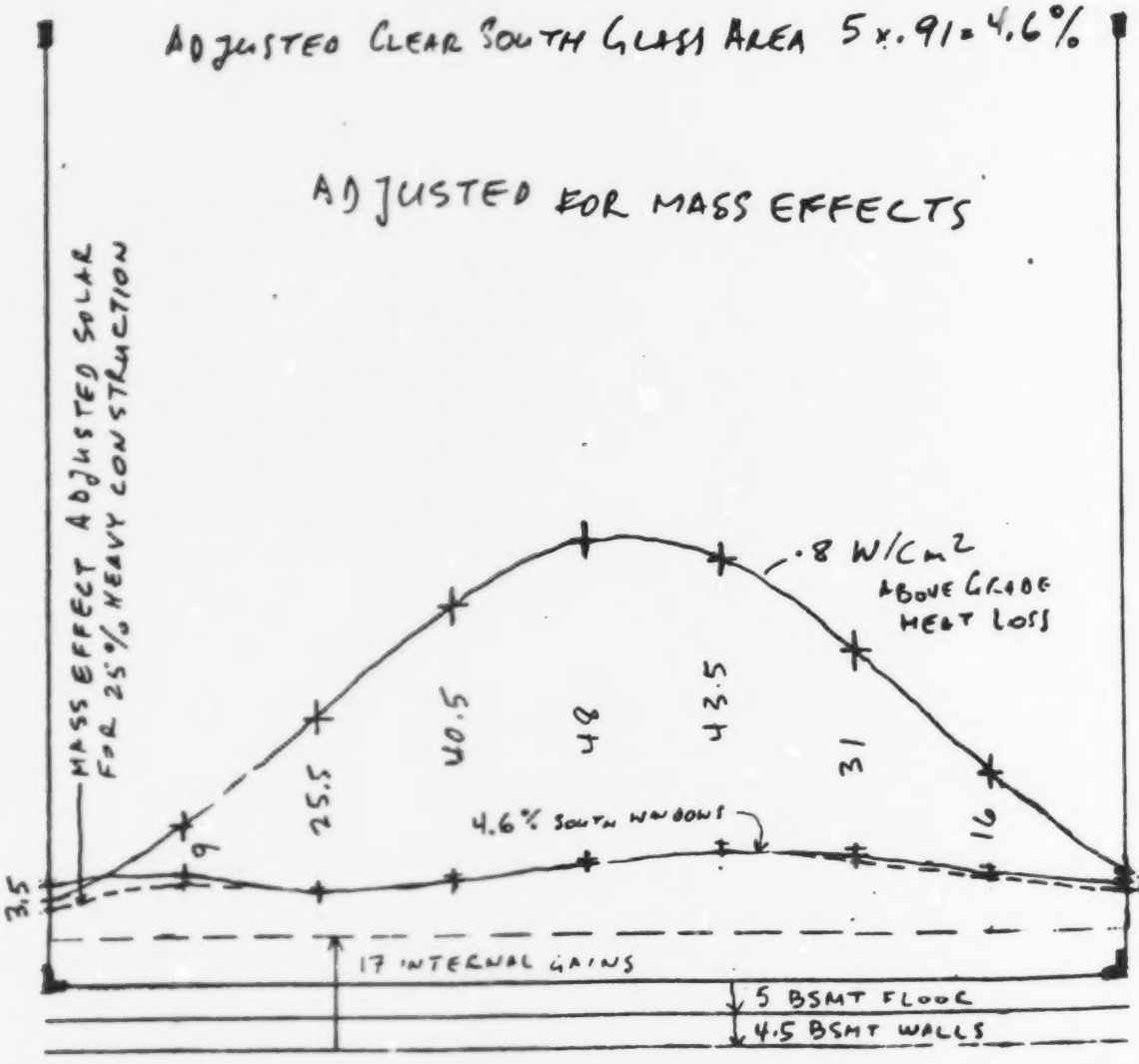
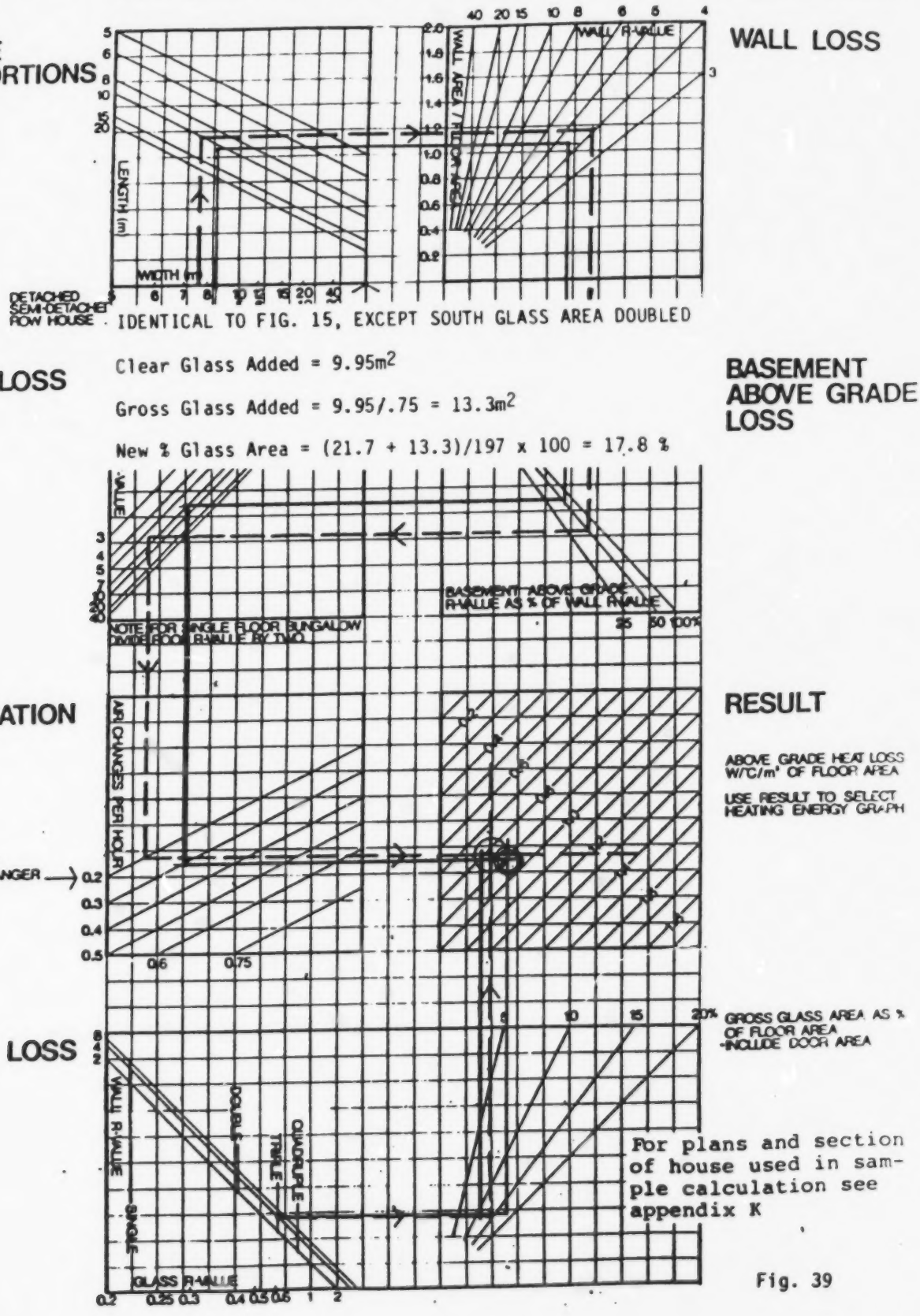


Fig. 38

ABOVE GRADE HEAT L[illegible] SAMPLE CALCULATION


HOUSE PROPORTIONS
WALL LOSS
ROOF LOSS
BASEMENT ABOVE GRADE LOSS
INFILTRATION LOSS
RESULT
GLASS LOSS
LENGTH (m)
WIDTH (m)
WALL R-VALUE
WALL AREA / FLOOR AREA
DETACHED
SEMI-DETACHED
ROW HOUSE
IDENTICAL TO FIG. 15, EXCEPT SOUTH GLASS AREA DOUBLED
Clear Glass Added = 9.95m²
Gross Glass Added = 9.95/.75 = 13.3m²
New % Glass Area = (21.7 + 13.3)/197 x 100 = 17.8 %
ROOF R-VALUE
BASEMENT ABOVE GRADE R-VALUE AS % OF WALL R-VALUE
NOTE: FOR SINGLE FLOOR BUNGALOW DIVIDE ROOF R-VALUE BY TWO
AIR CHANGES PER HOUR
TIGHT WITH HEAT EXCHANGER
ABOVE GRADE HEAT LOSS W/C/m² OF FLOOR AREA
USE RESULT TO SELECT HEATING ENERGY GRAPH
GROSS GLASS AREA AS % OF FLOOR AREA -INCLUDE DOOR AREA
WALL R-VALUE
SINGLE
DOUBLE
TRIPLE
QUADRUPLE
GLASS R-VALUE

For plans and section of house used in sample calculation see appendix K

Fig. 39

SAMPLE CALCULATION

For plans and section of house used in sample calculations see Appendix K

ABOVE GRADE HEAT LOSS COEFFICIENT .9 W/Cm^2

BASEMENT FLOOR LOSS 5 MJ/m^2/MONTH

BASEMENT WALL LOSS 4.5 MJ/m^2/MONTH

INTERNAL GAINS 17 MJ/m^2/MONTH

SOUTH GLASS (CLEAR) $\frac{19.9}{197} = 10.1\%$

TRIPLE GLAZING ADJUSTMENT .91

ADJUSTED CLEAR SOUTH GLASS AREA 10.1 x .91 = 9.2%

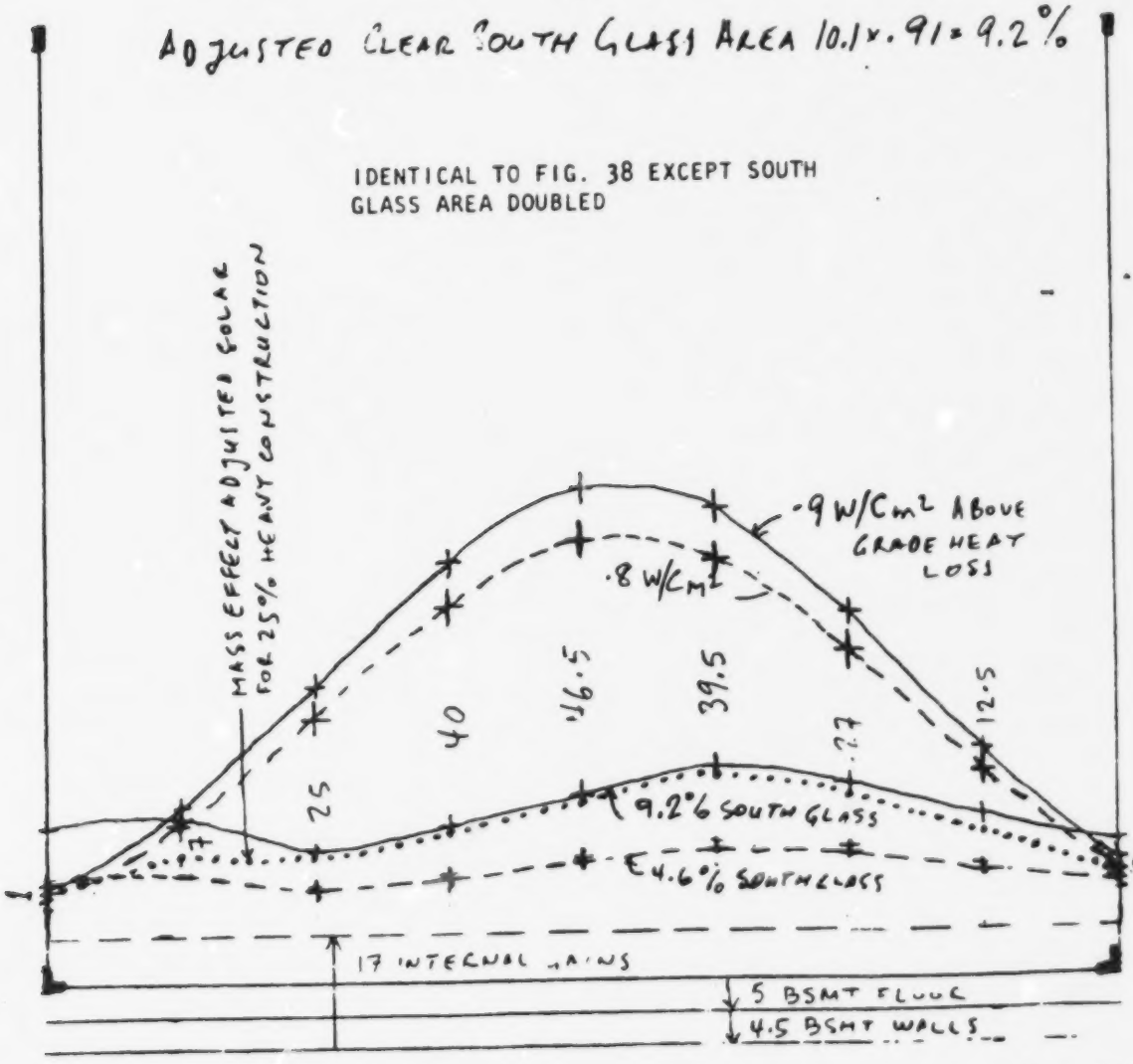


Fig. 40

MANUAL CALCULATION OF THE ABOVE GRADE HEAT LOSS COEFFICIENT

If the proportions of the house deviate from a rectangular box significantly, it may be desirable to carry out the manual calculation.

The manual calculation form "Above Grade Heat Loss" that follows contains all the necessary instructions and recommended input values. The form also includes the pre-calculation of the overall effects of increasing or reducing the glass area and of increasing or reducing the wall R-Value. These are the two quantities that are likely to be varied during design in order to attain the desired performance. The recommended air infiltration rates are listed on the calculation form.

ABOVE GRADE HEAT LOSS

For Wall, Ceiling and Basement Wall Above Grade R-values it is satisfactory to use the R-value of the INSULATION ONLY, since the additional resistance of air films and finishing materials is offset by adjustments for wood studs. With non-standard construction calculate resistance using ASHRAE procedures.

All units are metric, including insulation R values

PROJECT NAME _____

LOCATION _____

WINDOW LOSSES

WINDOW AREA (m2) Window dimensions to include frames, ie. use gross wall opening dimensions. Include sliding glass patio doors and basement windows. ①

WINDOW R-VALUE (Cm2/W) ②
.22 for single glazing
.41 for double glazing
.61 for triple glazing
.80 for quadruple glazing

WINDOW LOSS (W/C) ③
Divide Line ① by Line ②

DOOR LOSSES

DOOR AREA (m2) ⑩

DOOR R-VALUE (Cm2/W) ⑪
35mm Wood with metal storm .63
45mm Steel with urethane core .44

DOOR LOSS (W/C) ⑫
Divide Line ⑩ by Line ⑪

BASEMENT WALL ABOVE GRADE LOSSES

AREA (m2) ⑬
Wall area minus glass in basement wall above grade.

R-VALUE (Cm2/W) ⑭

LOSS (W/C) ⑮
Divide Line ⑬ by Line ⑭

SUMMATION OF ABOVE GRADE LOSSES

Sum all the previously calculated losses.

Window Loss	③
Wall Loss	⑥
Ceiling Loss	⑨
Door Loss	⑫
Basement Wall Above Grade Loss	⑮
Infiltration Loss	⑳

SUM of Above Grade Losses = ㉑ W/C

WALL LOSSES

WALL AREA (m2) Gross wall area minus window area and minus door area. Use inside house dimensions. ④

WALL RESISTANCE (Cm2/W)
(Multiply Imperial R values by .1761 to convert them to metric.) ⑤

WALL LOSS W/C ⑥
Divide Line ④ by Line ⑤

CEILING LOSSES

CEILING AREA (m2) ⑦

CEILING R-VALUE (Cm2/W) ⑧

CEILING LOSS (W/C) ⑨
Divide Line ⑦ by Line ⑧

INFILTRATION LOSSES

AIR CHANGE RATE Use measured infiltration AIR CHANGES/HR or the following estimated values:

-Older house (pre 1976)	1.0+ AC/hr
-Conventional construction (fossil fuel)	0.5 AC/hr
-Carefully constructed fossil fuel or average electrically heated house	0.3 AC/hr
-Super energy efficient air tight construction	0.05 - 0.1 AC/hr

Use .3 for the last case if there is no forced ventilation with heat exchanger. AC/hr ⑯

HEATED VOLUME Include semi-basement rooms that have walk out doors or large windows. Include 1/2 volume for normal basement spaces. m3 ⑰

FORCED CONTINUOUS VENTILATION m3/h ⑱

FORCED VENTILATION HEAT EXCHANGER EFFICIENCY % ⑲
Assume 70% if actual efficiency not available.

INFILTRATION LOSS

$$\left(⑯ \times ⑰ \times ⑱ \times \frac{100 - ⑲}{100} \right) \times 0.3345 = ⑳ \text{ W/C}$$

ABOVE GRADE LOSS PER UNIT FLOOR AREA

HOUSE FLOOR AREA m2 ㉒

ABOVE GRADE LOSS W/Cm2 ㉓
Divide Line ㉑ by Line ㉒.
Use ㉓ to select a heating energy graph.

ADJUSTMENT FOR ADDITIONAL WINDOW AREA

$$\frac{⑤ - ②}{② \times ⑤ \times 100} = \text{W/Cm2 } ㉔$$

NOTE: For each one percent INCREASE in window area, ADD ㉔ to ㉓.
For each one percent DECREASE in window area, SUBTRACT ㉔ from ㉓.

ADJUSTMENT FOR CHANGE IN WALL R-VALUE

NEW R-VALUE Cm2/W ㉕

ADJUSTMENT

$$⑤ \times \left(\frac{⑤}{㉕} - 1 \right) = \text{W/Cm2 } ㉖$$

NOTE: Add ㉖ to ㉓.
㉖ can be a negative number.

CALCULATION OF THE INTERNAL GAINS RATE

Internal Gains include heat from appliances, lighting and people body heat. The following fromula is suggested:

$$\frac{130}{\sqrt{A}} + 200 \times P/A$$

where

P - average occupancy or average persons during 24 hours

A - house floor area m^2

For 4 persons and 120 m^2 floor area this formula gives internal gains of 17 MJ/month/m^2, which is typical for a 3 bedroom house.

appendix C

OVERVIEW OF THE DETAILED MANUAL AND COMPUTER METHODS

A more accurate assessment of the final design may require the use of a detailed manual calculation method or a computer method.

The recommended manual method is "Calculation of Heat Loss, Heating Energy and Thermal Storage in Residential Construction", a joint publication of H.U.D.A.C and the Ontario Ministry of Energy. The present graphical method is largely based on this publication and is therefore compatible in methodology and concepts. The manual method allows for the more unusual plan and section configurations, partial basement insulation and an exact determination of the average wall and ceiling R-Value, allowing for stud and joist effects, air spaces, etc. The manual method allows to account correctly for attached unheated spaces, such as garages and sunrooms, as well as for the effect of solar gains into such spaces. Solar gains through other than south glazing can be accounted for, including gains through opaque walls and ceiling. The manual temperature swing calculation included in this publication allows a more detailed assessment of the effects of adjacent spaces, open doors, fan powered mass storage, internal gains, heat loss through walls, etc. Complete weather data is included for 20 Ontario locations.

A detailed manual below grade basement loss calculation methodology is presented in "Basement Heat Loss Studies at DBR/NRC" by G.P. Mitalas, National Research Council Canada publication Nr. NRCC 20416. A great variety of possible basement insulation configurations are covered. The corner effects, and ground conductivity effects can be calculated with the help of the step by step methodology included in the publication.

There are two public domain microcomputer programs available in Canada: the "CMHC-2" and the "Hot Can". The "CMHC-2" program, developed by the Central Mortgage an Housing Canada, allows the calculation of infiltration from construction details of the house. The "CMHC-2" program also allows the determination of the cost-effectiveness of the various energy conserving features through the use of the cost data base and the economic evaluation routines that are included in the program. Shading effects are not included. The "Hot Can", developed by the National Research Council Canada, uses the infiltration rate as estimated by the user. It includes the calculation of the overhang shading effect, although in a rather approximate manner. Detailed below grade basement loss calculation is included. Neither of the two microcomputer programs includes the facility to calculate the temperature swing.

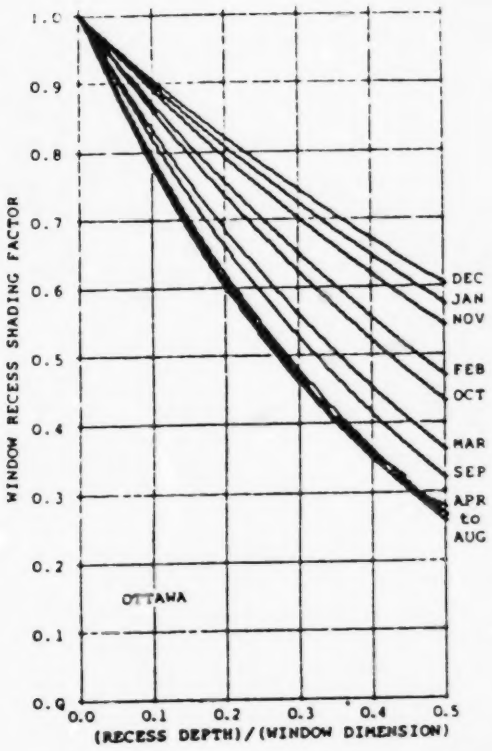
SHADING BY RECESSING OF WINDOWS

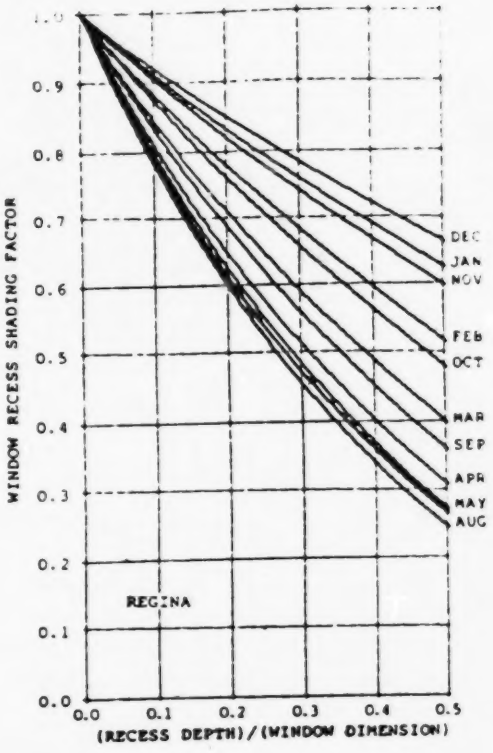
The walls may be quite thick in a superinsulated house, or a house with thermal mass in the exterior walls. The window opening in such thick walls can shade out a substantial portion of the solar gains. All three categories of radiation gains are affected by window recessing, namely beam, sky diffuse and ground reflected radiation.

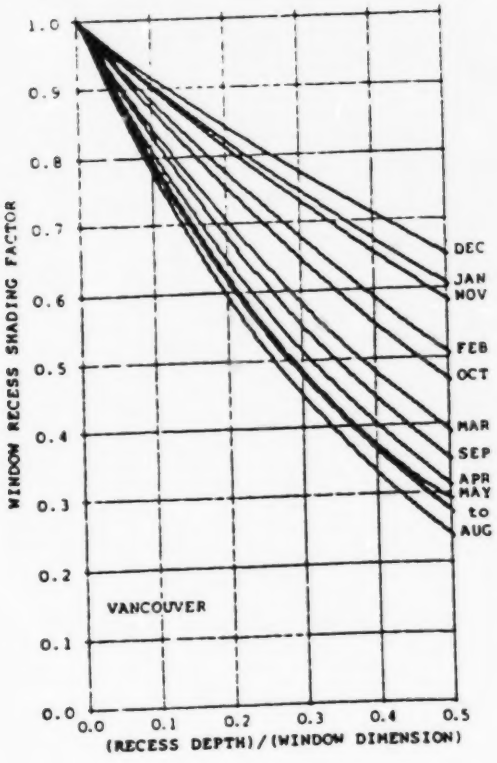
Both the outdoor portion and the indoor portion of the window recess contribute to the shading. Due to the reflectivity characteristics of glass at low angles of incidence however, the indoor portion contributes substantially less so that only the outdoor portion needs to be considered in a practical case. The indoor portion can be said to reduce the effective absorptivity of the window opening in the same manner as anything else that makes the window appear less dark when viewed from the outside.

Shading due to window recessing varies with latitude, local characteristics of solar radiation (e.g. cloud amount), time of the year and the width to height ratio of the window. The most important factor is the ratio of the depth of the recess to the window dimension. The Window Recess Shading graphs on the following page are obtained from hourly computer calculations over the year for the different locations. A square window is assumed (height equals width). The finish of the recess is assumed to have low reflectivity. Factor to be applied to solar gains is plotted against the ratio of the recess depth to the window dimension (width or height, since the window is square).

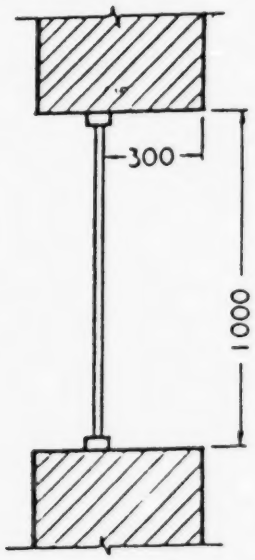
WINDOW RECESS SHADING GRAPHS







EXAMPLE OF WINDOW RECESSING EFFECT CALCULATION



Assume that the windows of the Sample Calculation House are recessed as shown at left.

Recess depth to window dimension ratio is:

300 / 1000 = 0.3

Window Recess Shading Factor Graph for Ottawa gives the following shading factors:

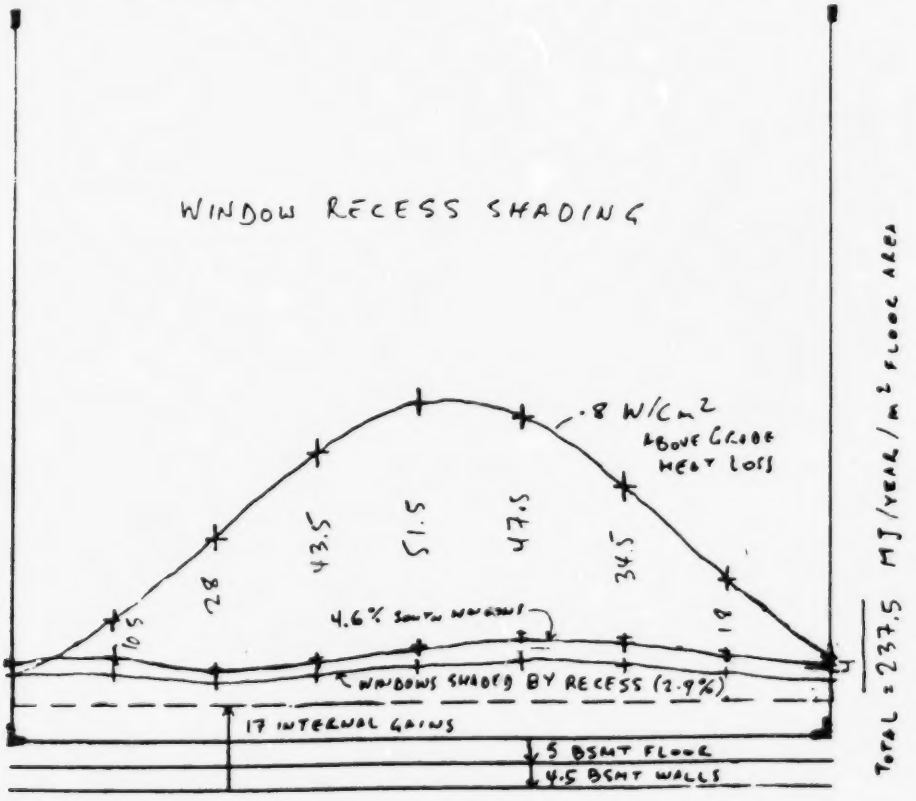
September	- .53
October	- .62
November	- .69
December	- .74
January	- .72
February	- .65
March	- .56
April	- .47
May	- .45

For a seven month heating season the average factor is:

(.62+.69+.74+.72+.65+.56+.47) / 7 = .64

To adjust for the shading effect multiply the window area by the average shading factor:

Window Area Adjusted for the Window Recess Shading = 4.6% x .64 = 2.9%



SHADING BY NEARBY TALL OBJECTS

Shading by tall objects in front of or to the side of a window has an effect on all three solar gain components, namely beam radiation, sky diffuse radiation and ground reflected radiation. Since there are many possible configurations of such objects with the glazing, only a general discussion of the approximate shading effects and some "rules of thumb" can be given.

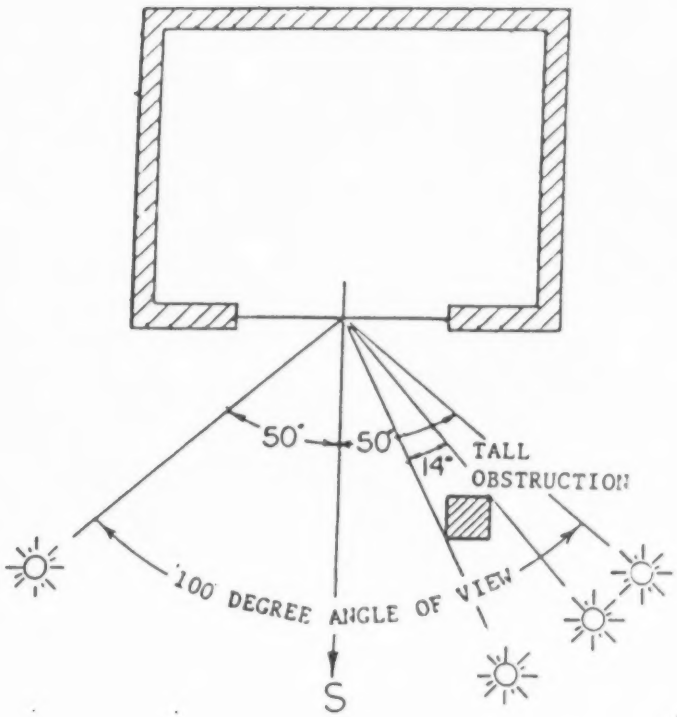
The effect of such objects on ground reflected and sky diffuse radiation gains is constant at all times of the year. The beam radiation shading varies with time due to the sideways (azimuthal) motion of the sun.

If the obstructing object is in front of the window, close to and much larger than the window, such as a tree, it may shade the window at all times. Bare branches of a tree can shade out 20 to 40% of the solar gains. If the object is solid, relatively slender and close to the window then it will shade out its projected area on the window all times, even though the shadow will move and will shade different parts of the window at different times.

The more difficult cases arise with objects that are at a distance or at the side so that they cast a shadow on the window only during a portion of the day. One general rule of thumb for dealing with such cases is shown in the illustration on the next page and can be described as follows.

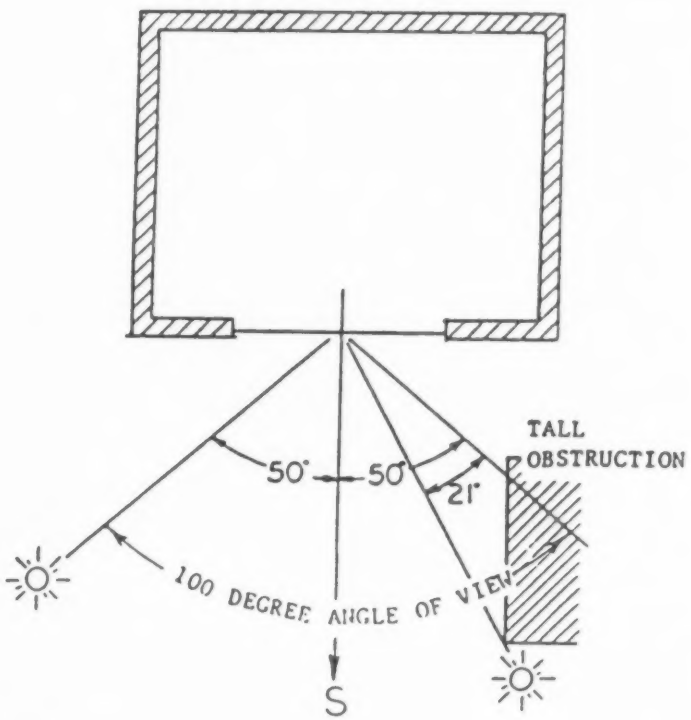
On a plan showing the size and the position of the obstruction as well as the window, draw a line from the centre of the window and at right angle to the window. Draw in two lines at 50 degrees from this line, again originating at the centre of the window. The two lines delineate the "100 degree angle of view" of the window. Such a restricted angle of view compensates for the lower solar gains at shallow angles of incidence.

Any obstruction within the angle of view will shade the window. The shading angle is equal to the angle between the lines from the centre of the window to the edges of the obstruction. If only one side of the obstruction is within the angle of view, then measure only to the edge of the angle of view. Since a 100 degree angle of view is being considered, the shading angle also equals the shading fraction in %. To express the shading fraction as a fraction, divide the shading angle by 100. Factor to be applied to the solar gains equals unity minus the shading fraction. Shading fractions of several obstructions may be added together in determining the overall solar gains factor. For details of this rule of thumb see the two examples on the following page.



Obstruction entirely within the "angle of view". Therefore angle subtended by the obstruction represents the shaded fraction $\frac{14}{100} = .14$

Factor to be applied to the solar gains is 1 - .14 = .86.



Obstruction is partially within the "angle of view". Measure the shaded fraction from side of angle of view to edge of obstruction.

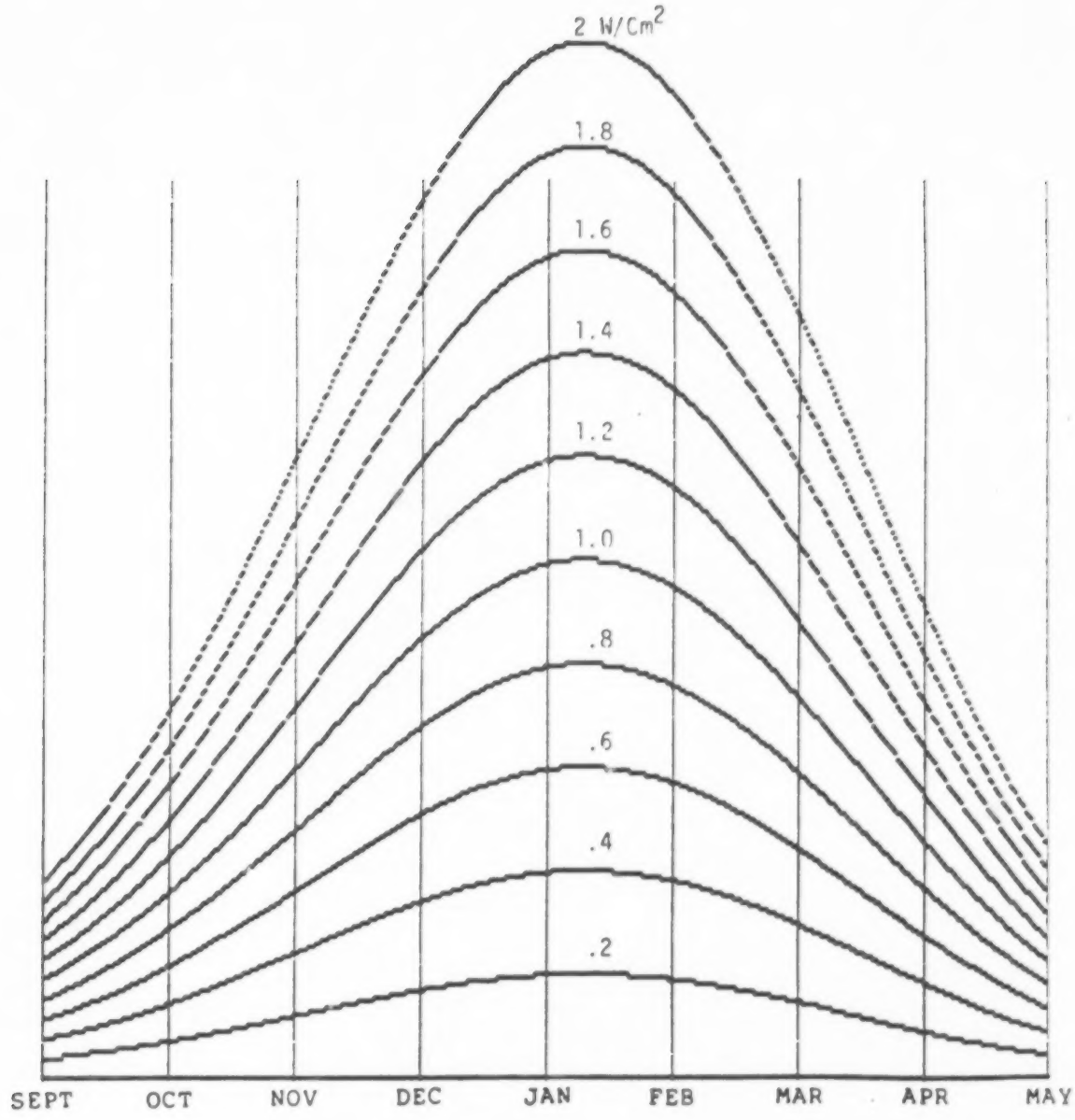
Shaded fraction is $\frac{21}{100} = .21$.

Factor to be applied to the solar gains is 1 - .21 = .79.

Note that this case can be treated as projected wall at the side of the window. The answer from the graph for this case is .78.

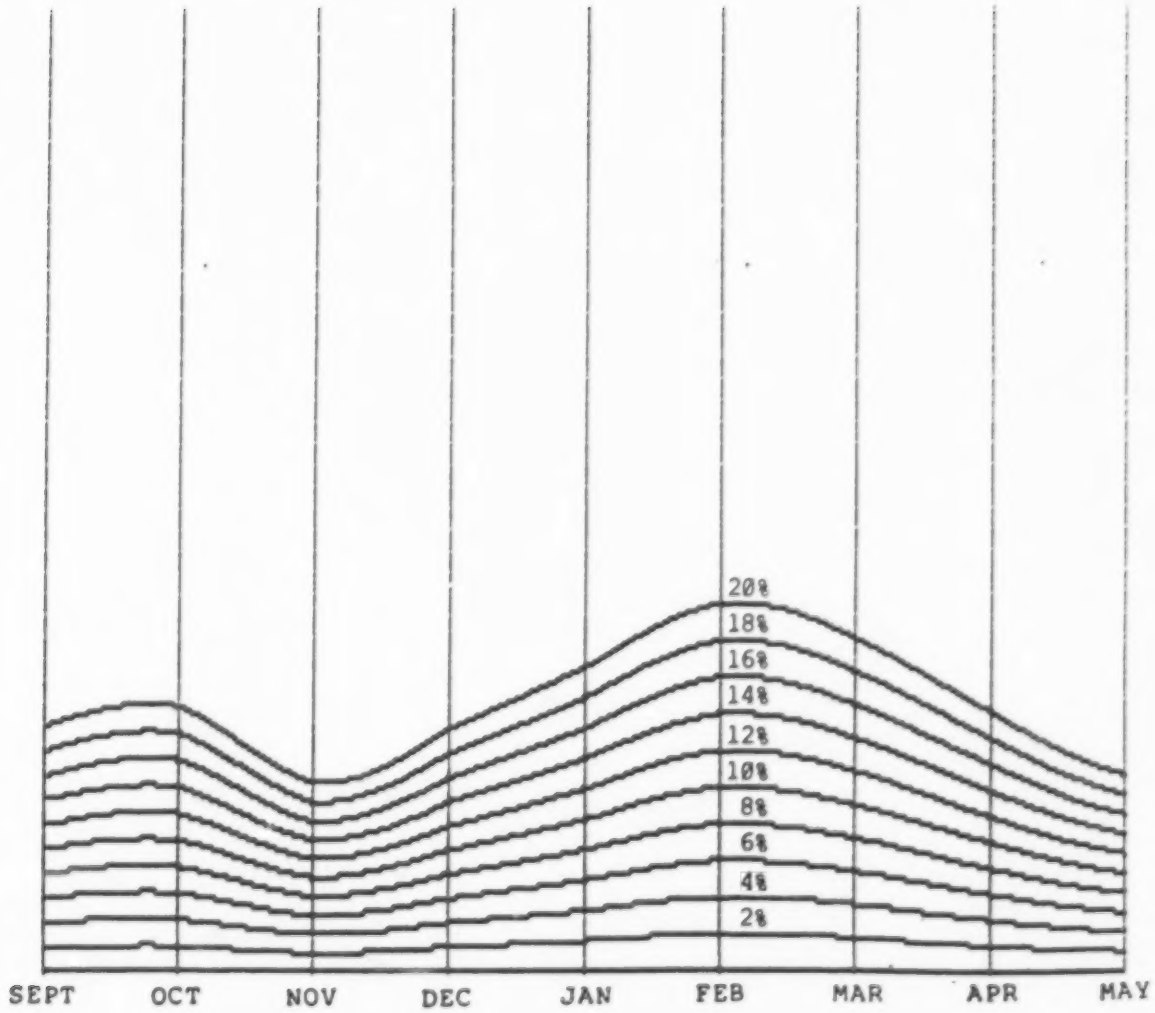
O T T A W A

H E A T I N G E N E R G Y G R A P H



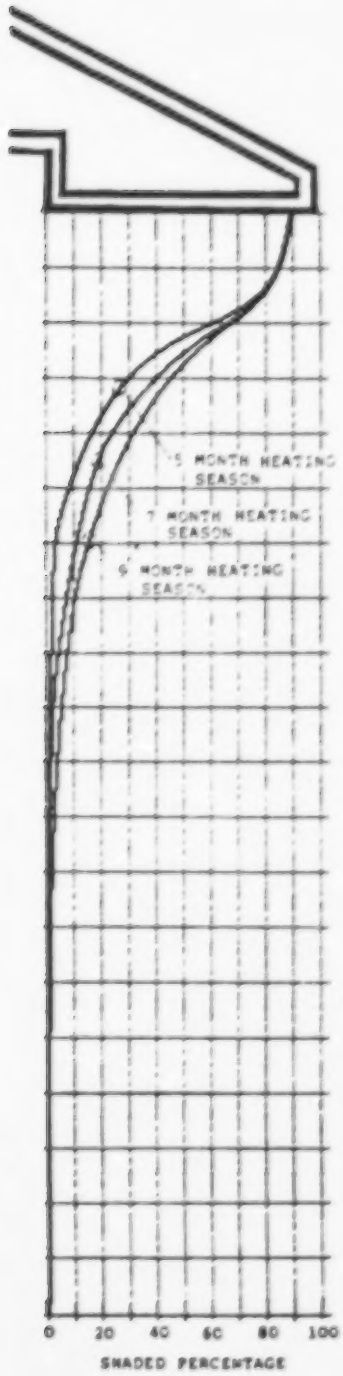
O T T A W A

S O L A R G A I N S G R A P H

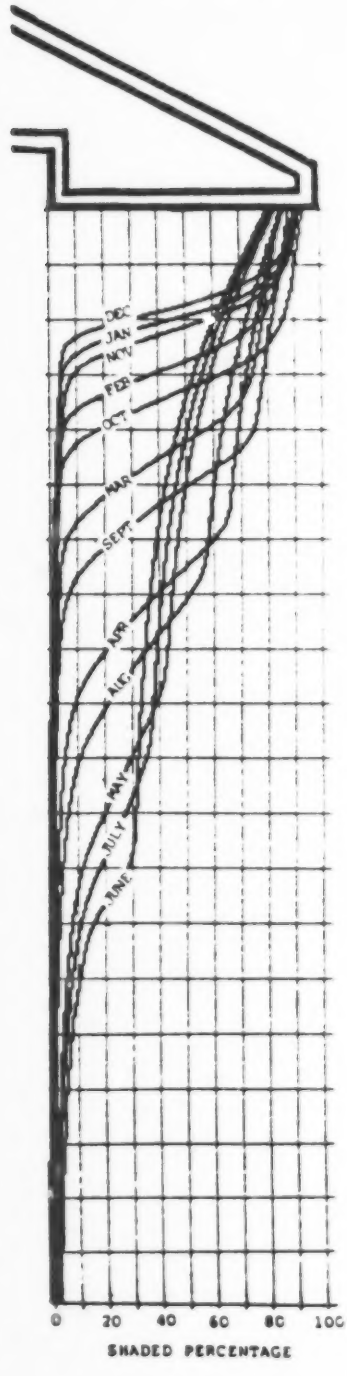


O T T A W A

SEASONAL SHADING GRAPH



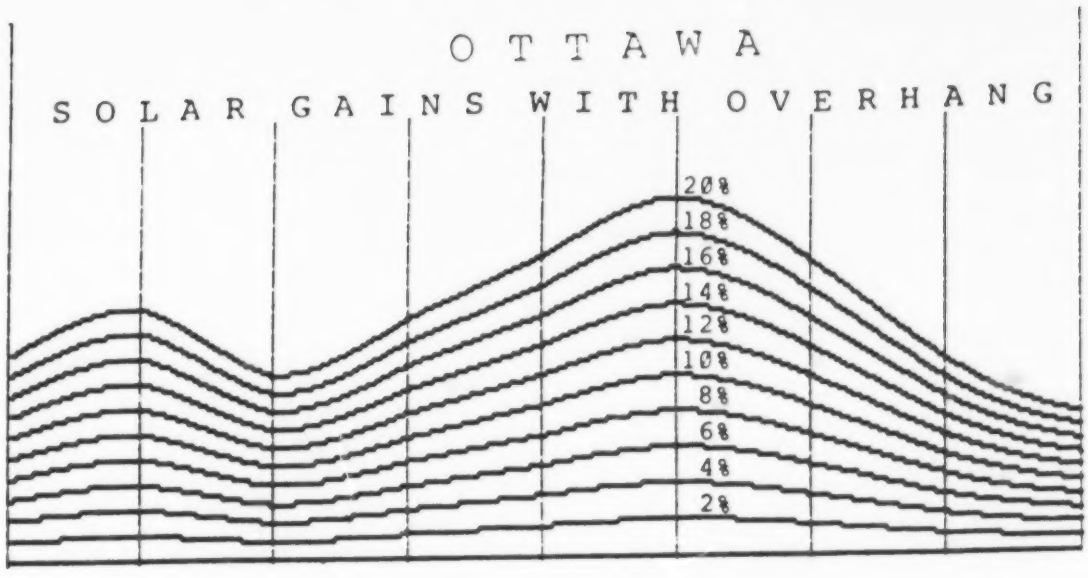
MONTHLY SHADING GRAPH

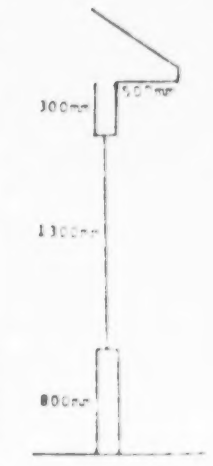


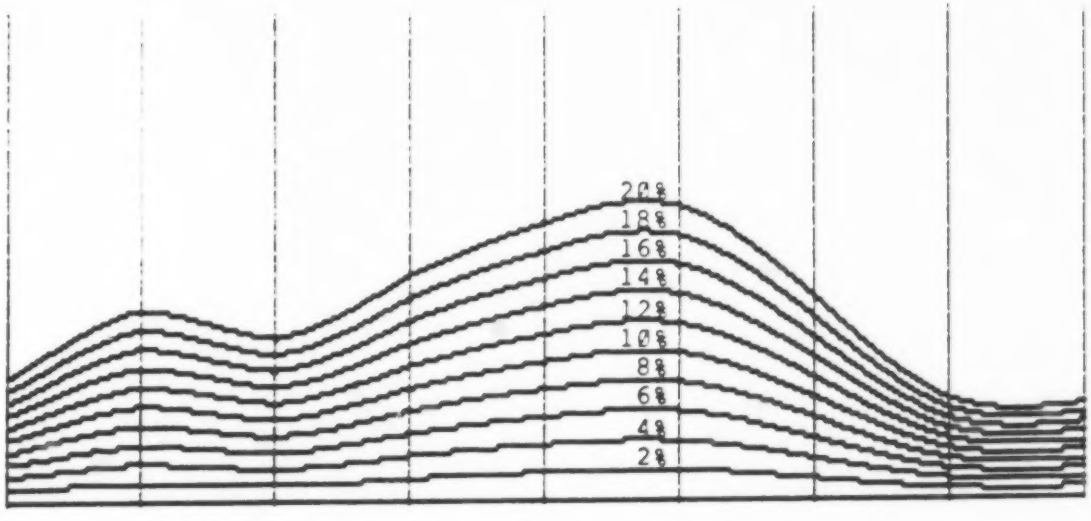
O T T A W A

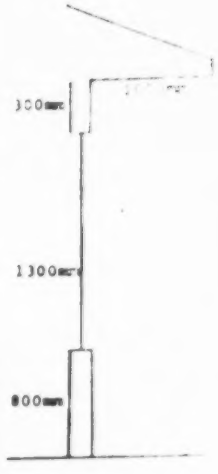
S O L A R G A I N S W I T H O V E R H A N G

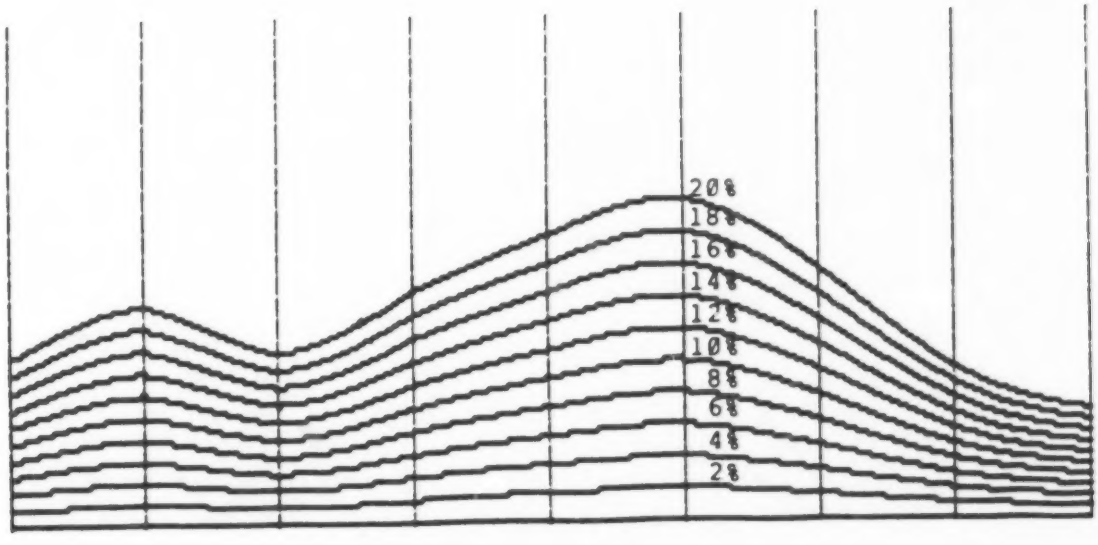
F-4

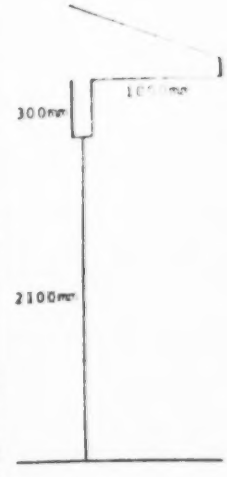






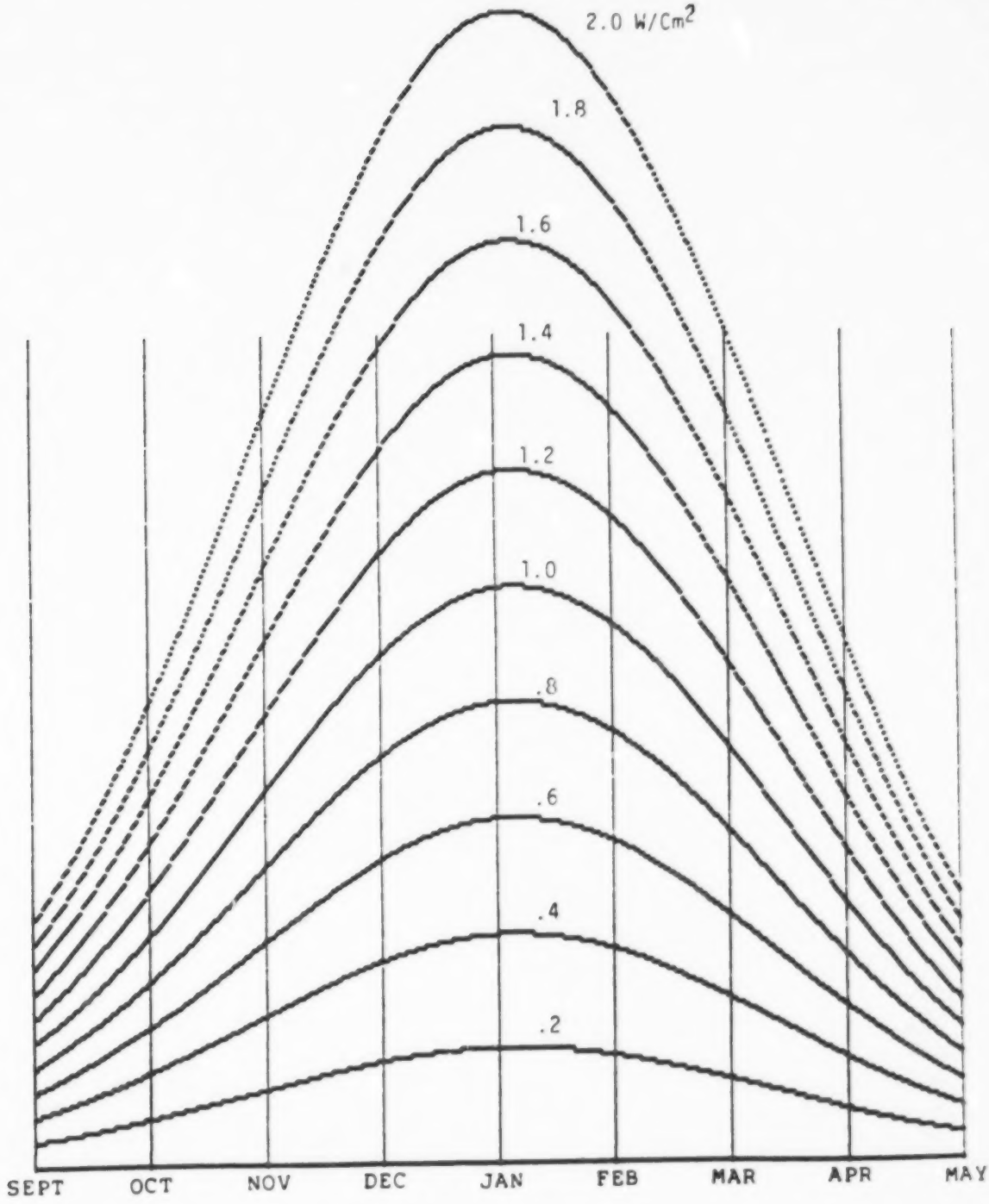






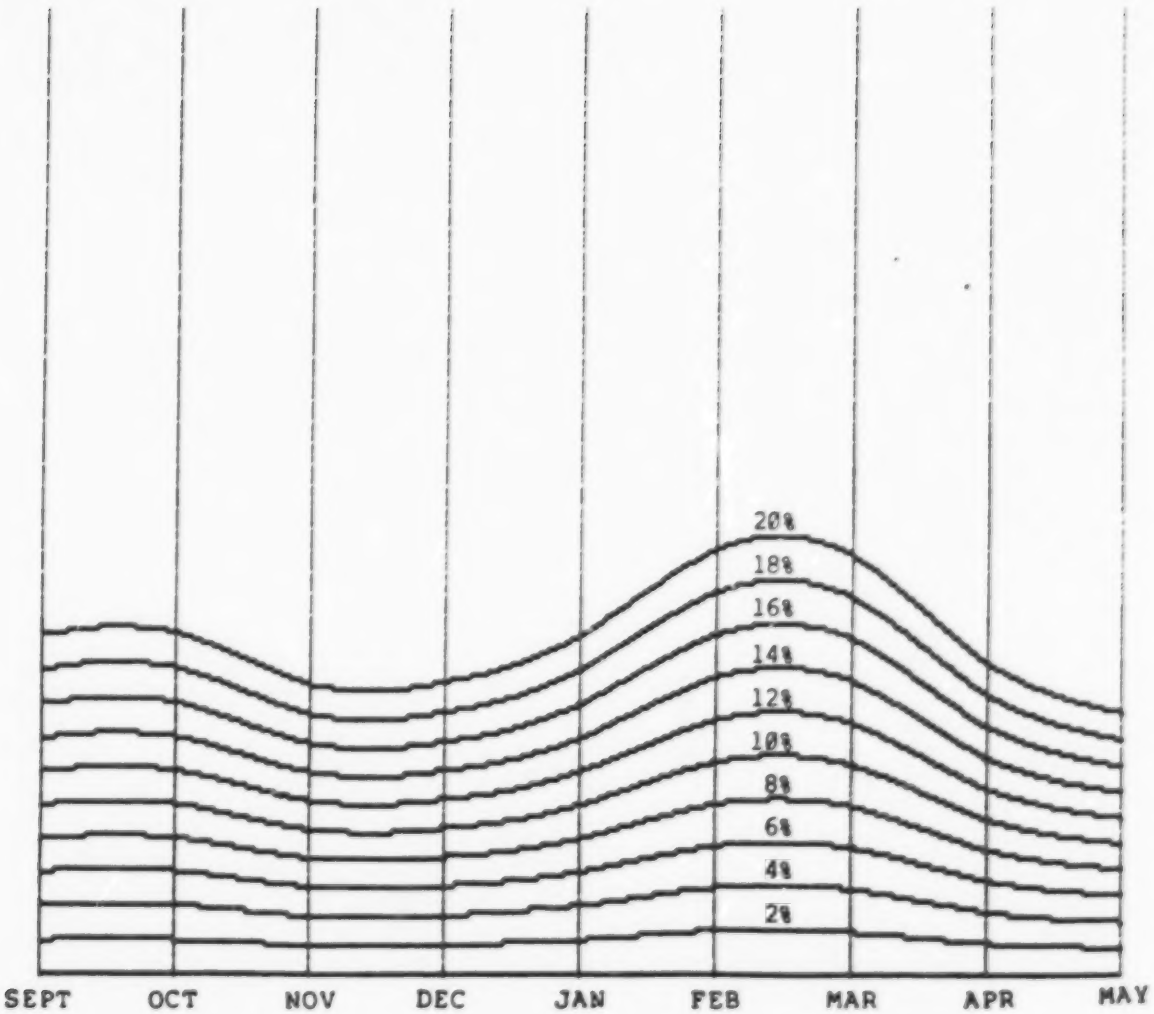
REGINA

HEATING ENERGY GRAPH



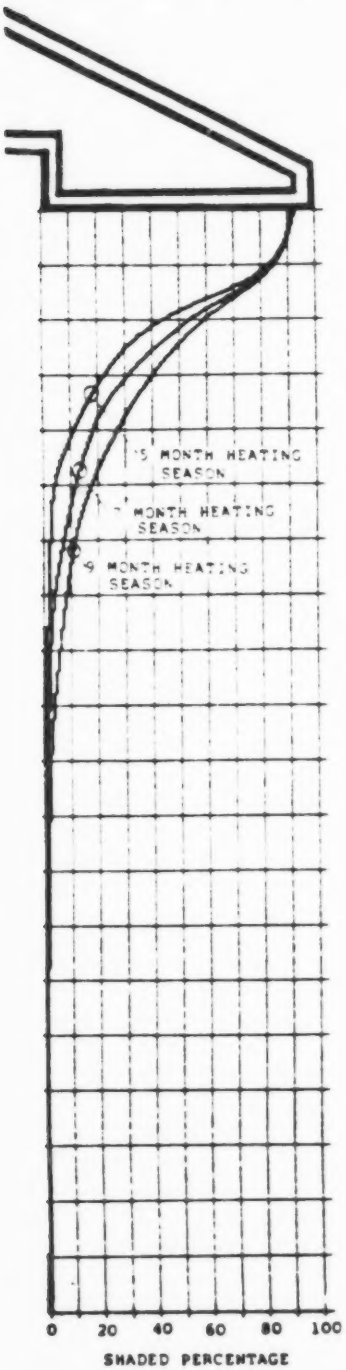
R E G I N A

S O L A R G A I N S G R A P H

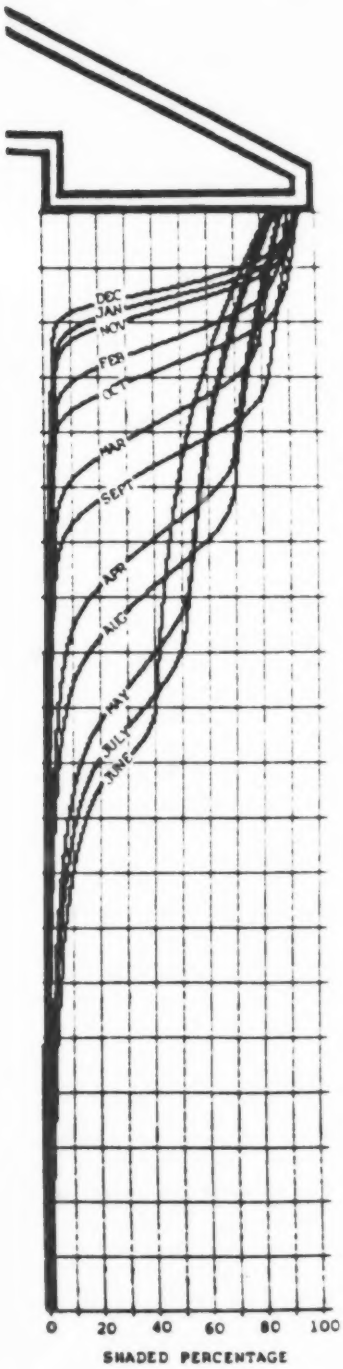


R E G I N A

SEASONAL SHADING GRAPH

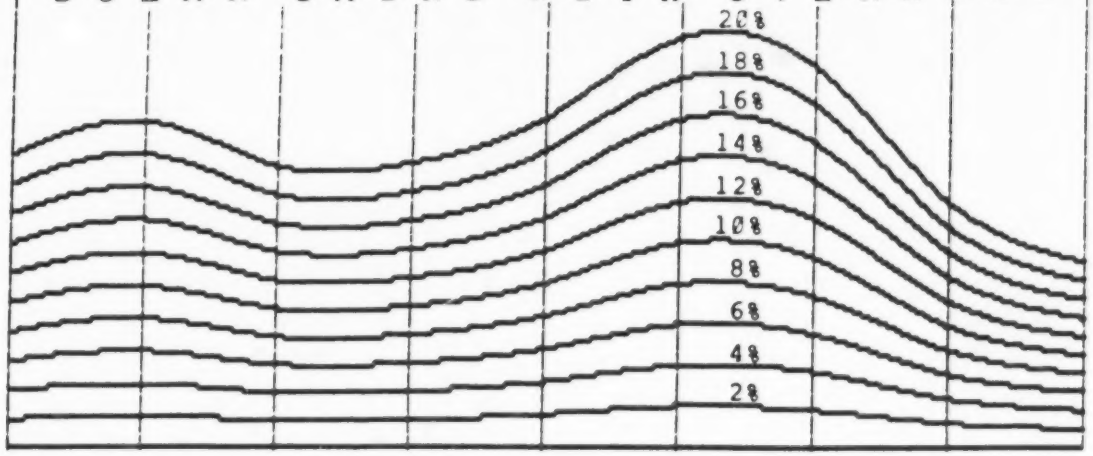


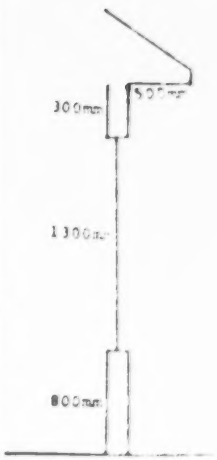
MONTHLY SHADING GRAPH

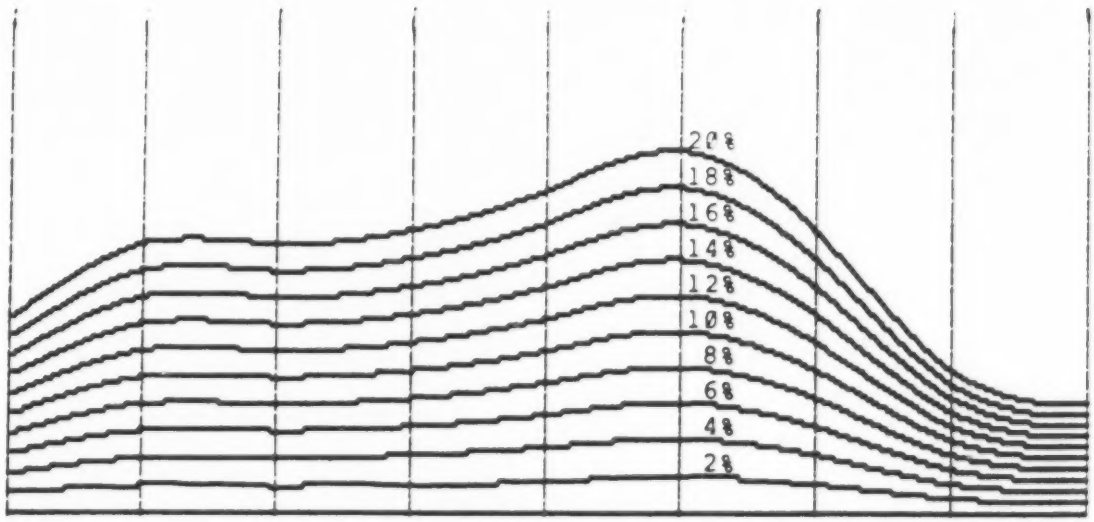


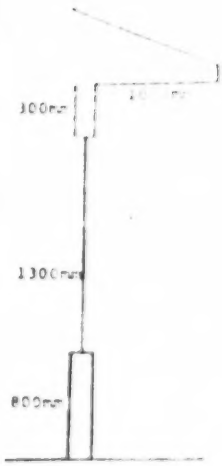
REGINA

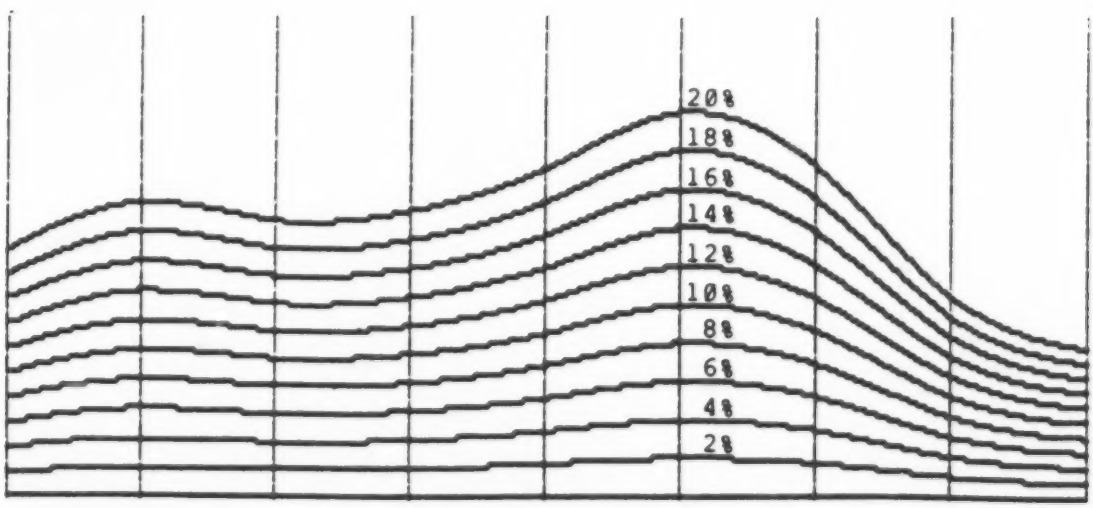
SOLAR GAINS WITH OVERHANG

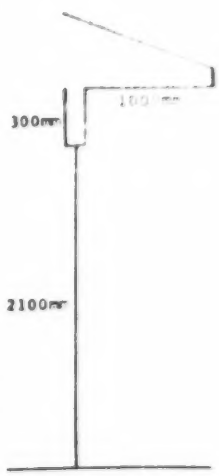








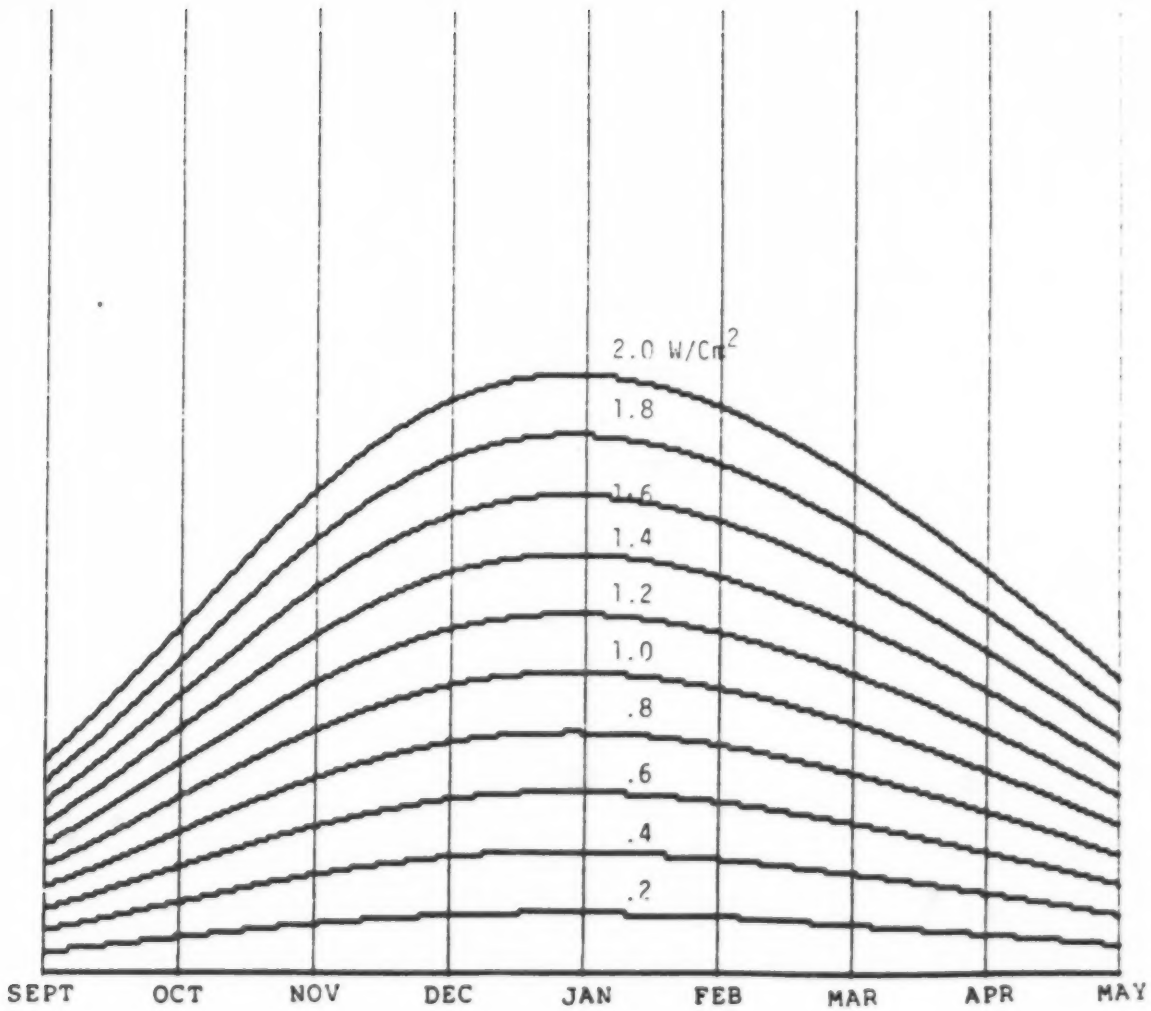




appendix II

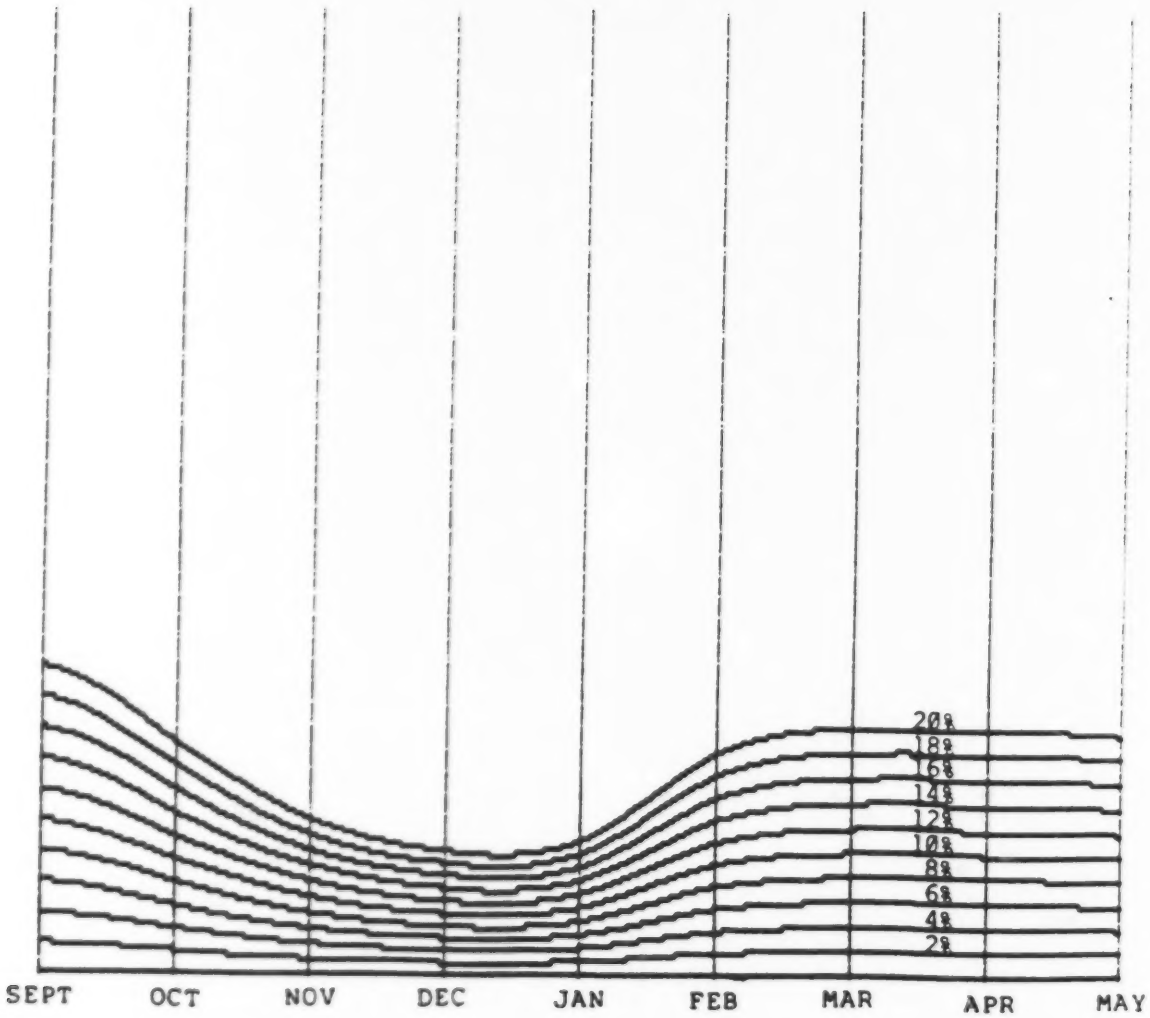
V A N C O U V E R

H E A T I N G E N E R G Y G R A P H



V A N C O U V E R

S O L A R G A I N S G R A P H



V A N C O U V E R

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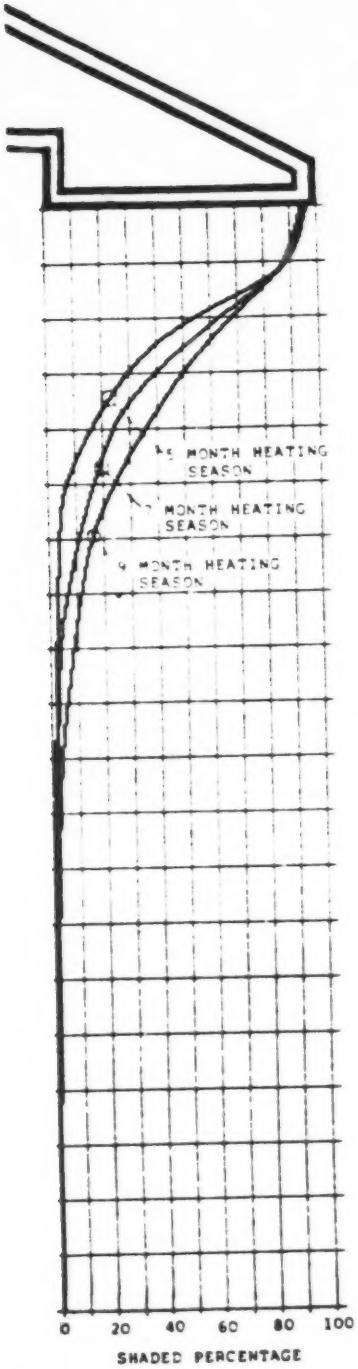
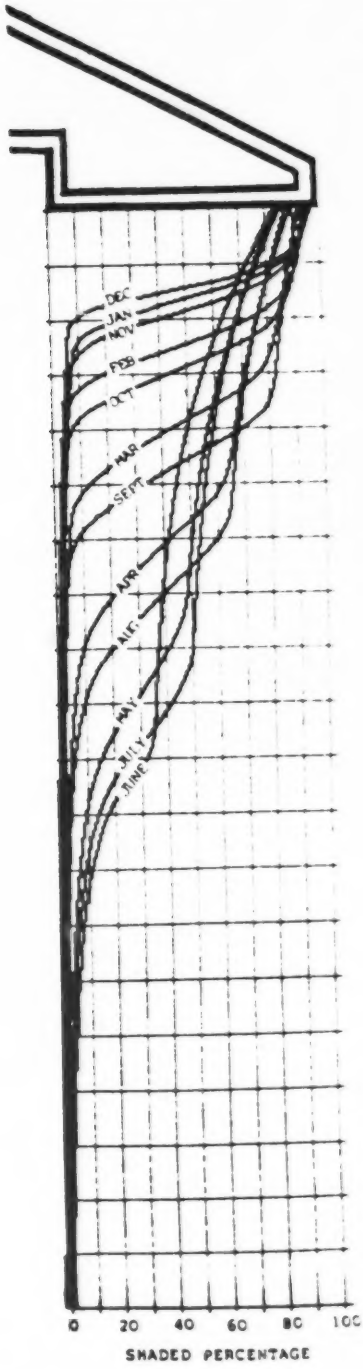
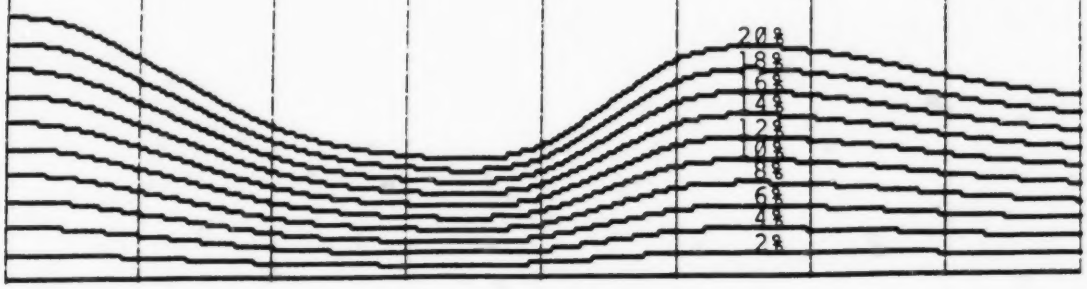


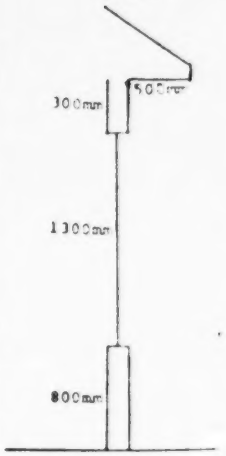
MONTHLY SHADING GRAPH

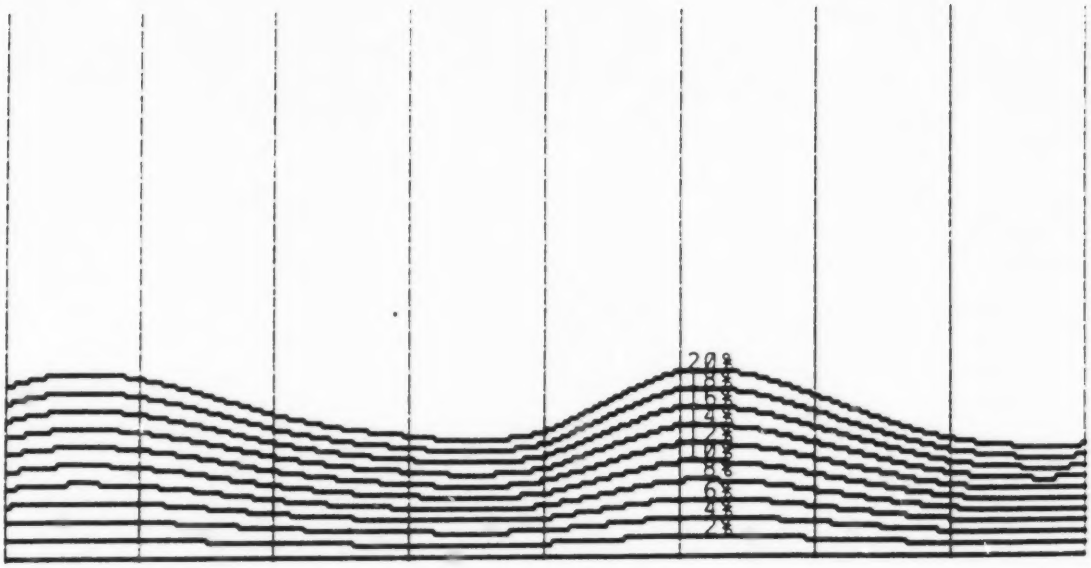


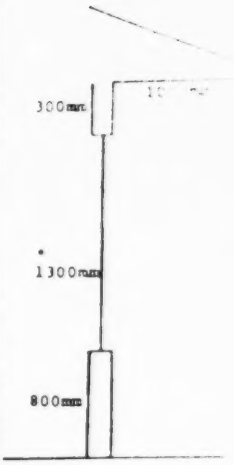
V A N C O U V E R

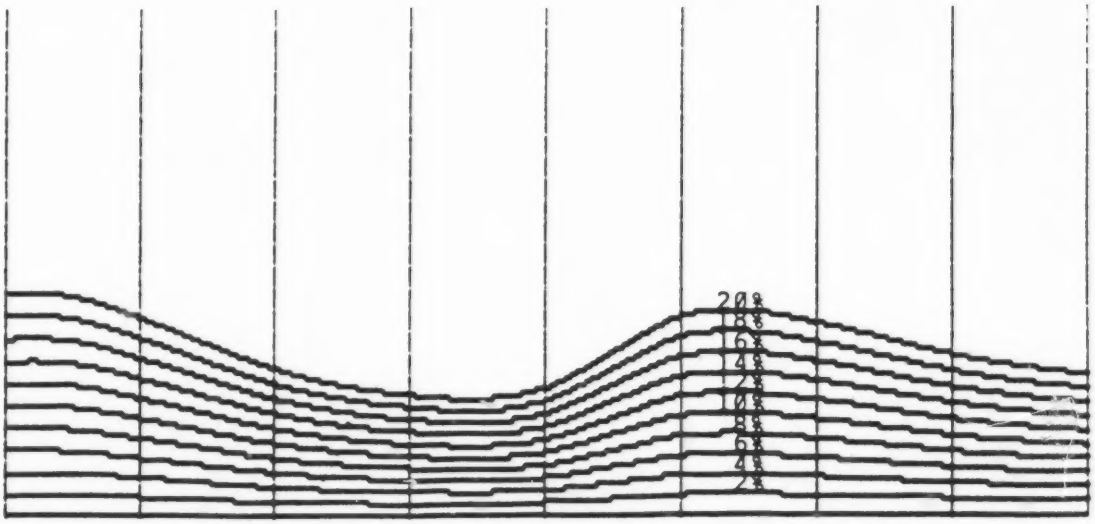
S O L A R G A I N S W I T H O V E R H A N G

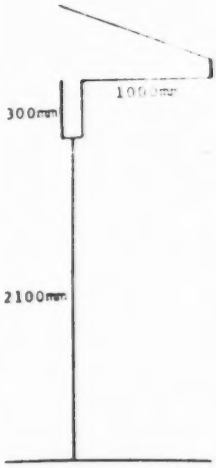












PREPARATION OF DESIGN GRAPHS FOR OTHER LOCATIONS

Heating Energy Graph

Use the monthly heating degree days (below the base of 18 C). Divide the degree days of each month by the appropriate number of days in the month. For February use 28.25 days to allow for the averaging effect of leap years. Next multiply degree days of each month by 30.42 (average length of month during the heating season) and add 60.48 to each month (to adjust to the space temperature of 20 C). Next multiply the results for each month by .0864 to convert degree days to MJ/W. Plot the final results on 9 equally spaced vertical lines, using a 1:100 scale. Horizontal scale is not important. The plot will be correct for a Heat Loss Coefficient of 1 W/Cm2. Multiply the resuts for each month by 2 to get the 2 W/Cm2 curve. The remaining curves are obtained similarly by multiplying the monthly results by 1.8, 1.6, 1.4, 1.2, .8, .6, .4 and .2.

Solar Gains Graph

Obtain the monthly solar gains through ordinary vertical double glazing for a location with such data that is closest to your location. Reference 9 gives such data for 20 Ontario locations in MJ/month/m2 of vertical glass. Divide the monthly solar gains by the appropriate number of days in the month and then multiply by 30.42. Next divide the results for each month by 10 to obtain the correct values for 10% glazing. Plot the final results on 9 equally spaced vertical lines using a 1:100 scale. Horizontal spacing of the vertical lines must be the same as that used for the Heating Energy Graph. The plot will be correct for the 10% glazing curve. The remaining curves are obtained by multiplying the monthly results by 2, 1.8, 1.6, 1.4, 1.2, .8, .6, .4 and .2.

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2. Energy-Efficient Housing Construction, NHA 5488, CMHC, Ottawa, 1982

3. Builders' Guide to Energy Efficiency in New Housing, Housing and Urban Development Association of Canada, Toronto, 1980

4. Residential Passive Solar Design and Construction Project, Design and Construction Reports, Ontario Ministry of Energy, Toronto, October 1981

5. Modest House Designs, NHA 5184, Ottawa, 1977

6. Residential Standards, NRCC 15563, NRC, Ottawa

7. Proposed Changes for the Next Edition of the Measures for Energy Conservation in New Buildings (NRCC 16574), NRC, Ottawa, 1982

8. HOTCAN: A Computer Program for Estimating the Space Heating Requirement of Residences, by R.S. Dumont, M.E. Lux and H.W. Orr, CP 49, NRC, Ottawa, 1982

9. Calculation of Heat Loss, Heating Energy and Thermal Storage in Residential Construction, HUDAC and Ontario Ministry of Energy, Toronto, 1983

10. Basement Heat Loss Studies at DBR/NRC, by G.P. Mitalas, NRCC 20416, NRC, Ottawa, 1982

11. Residential Passive Solar Heating, Review and Development of Design Aids, Ontario Ministry of Energy, Toronto, 1980

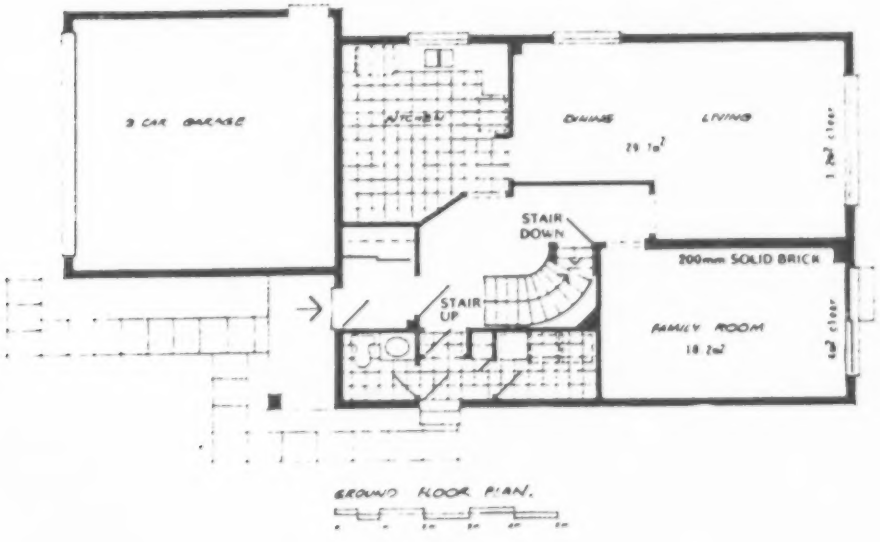
12. A Rational Manual Method for Determination of Space Temperature Swing Due to Solar Gains, by E.L. Cuplinskas, Proceedings of ASHRAE & U.S. Department of Energy Joint Conference on The Thermal Performance of the Exterior Envelope of Buildings, Orlando, Florida, 1979

13. Manual Calculation of Temperature Swing in Direct Passive Solar Heating Systems, by E.L. Cuplinskas, Proceedings of the SESC Conference at Vancouver, B.C., 1980

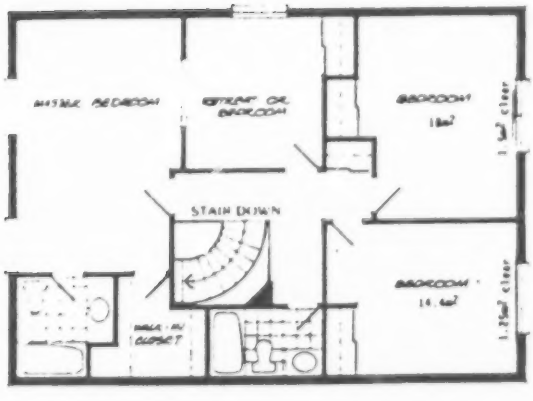
14. A Simple Method for Determining the Heating Requirements of Direct Gain Passive Solar Houses, by S.A. Barakat and D.M. Sander, B.R.N. No. 195, NRC, Ottawa, 1982

appendix K

PLANS AND SECTION OF HOUSE USED IN SAMPLE CALCULATIONS

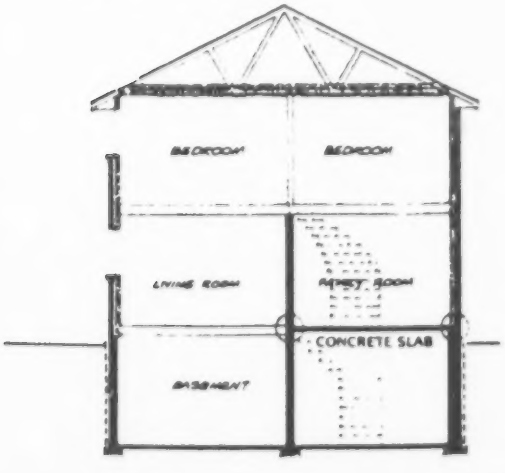


GROUND FLOOR PLAN.



SECOND FLOOR PLAN.

Floor Area	197m^2	
Windows	Triple Glazed	
Total Window Area (gross masonry opening)	21.7m^2	
South Window Area (clear)	9.95m^2	
Insulation:		
Walls	4.6m^2.C/W	
Ceiling	7.0	
Basment Walls	2.6	



SECTION

Ontario Residential Passive Solar
Design and Construction Project
House No.10
Builder: Geo Wimpy Canada Ltd.
Designer: IBI Group

POOR

QUALITY

ORIGINAL